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BEN GURION UNIVERSITY OF THE NEGEV

Department of Biology

Department of Occupational Health

(6) ACCUMULATED EFFECTS OF WORK UNDER HEAT STRESS.

(9) Final Rep[redacted]t.

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Beer Sheva, Israel.

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This report was submitted to the Senate of the Ben Gurion University of the Negev by A. Gertner as part of the requirements for the degree of Doctor of Philosophy.

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INTRODUCTION

There is no doubt that environmental conditions can have a marked effect on the worker's health. As early as the eighteenth century Percival (19) observed that cotton mill workers were "disposed to develop fevers and their constitutions were undermined by hot and closed atmospheres". In the earlier part of the twentieth century, investigations showed that when heavy work is performed at high temperatures the sickness rate increases (8,17,59,103,104, 105,106,118).

In a study of 23,000 coal miners (106), time lost due to sickness was 63% higher in miners working at temperatures above 27°C than in those working at temperatures of 21°C or less. Death rate increase of about 35% was found in 1937 (118) for miners working in hotter mines. In another study, Britten and Thompson (17), found organic heart defects were more frequent in foundry workers. Enlarged hearts and arteriosclerosis were found more often among steel and glass workers.

A major part of our country is situated in the warm Negev. There are various industrial plants and settlements in this region. The future of this area calls for further industrial development as well as the continued establishment of new settlements. Therefore the question arises; can work and residence in this warm environment present a hazard which will ultimately affect the health of these individuals. The assumption underlying this work was that any knowledge that can shed light on this question, is of vital interest to the further development of this region and most important to the welfare of its present and future inhabitants.

In view of the health hazards that can arise from work in hot area, many have sought to alleviate the problem by simply reducing or eliminating the heat stress. Environmental heat stress can be diminished by suitable behavioural patterns such as: (a) discarding of superflous clothing, (b) avoidance of excessive food intake, (c) attention to an adequate intake of water and salt to replace the losses in sweat, (d) practising of economy in the expenditure of muscular energy, and (e) ordering one's existence so that the heaviest and most exacting tasks are performed in the coolest part of the day.

Science and technology can also be applied to the artificial mitigation of heat stress by: (a) correct architectural design of houses and other buildings, (b) proper use of fans and evaporative coolers, and (c) employment of air-conditioning.

There are some who think that air-conditioning by itself is the complete answer to warm environments. This is not so. Its uses are strictly limited. It is successfully applicable only in situations where for reasons of social convention or otherwise everyone is dressed alike and is engaged in roughly the same level of muscular work. It cannot be used in many situations in which men have to work, such as outdoors in summer. Further, it is not economically feasible to use in some industries, such as mining at great depth and in the steel and glass industries. Dictated paced work under unfavorable climate conditions as seen in agricultural and building work places also preclude allevation of heat stress. Since most of the above mentioned limitations must be taken into account in present and future development plans for the Negev, the following key questions need to be addressed. 1) How do workers who work in a warm environment for a major part of the year respond

physiologically during their normal work shifts? 2) Can work in a warm environment for a major part of the year ultimately adversely affect the worker's health?

The first question has been for the most part been approached by conducting experiments under controlled laboratory conditions. Contrary to these conditions, the habitual activity of a worker during his normal work shift is characterized by the natural occurrence of mixed dynamic patterns. Many combinations of work and rest of differing durations and intensities occur. Further, the worker moves in thermally differing "zones" at the work site while temperatures within these zones may vary with time as well. Therefore, since the laboratory experiments can not simulate "real life" situations, the information derived from them may not always truely reflect what happens when an individual is exposed to a warm environment during his normal eight hour work shift. Unfortunately studies on man during his work shift in his natural environment have been very few. Even fewer addressed themselves to the overall physiological reactions in the natural environment. Thus in order to shed some light on this important question the physiological reactions of workers <u>during their normal work shifts in a warm environment</u> were studied. In particular, electrolyte, fluid, hormonal and cardiovascular responses were investigated.

The second question concerning cumulative affects, has been approached in the past by studies of the survey format. Unfortunately, it is not possible on the basis of reports made several decades ago to estimate the extent to which in today's industry the worker's health is affected by working in hot environments. More importantly, it is not possible to distinguish in these studies between the effects of the occupational health hazards, and the health hazards

of working in a hot environment.

In the present study a slightly different approach was taken. It would have been ideal to isolate the effects of the occupational health hazards on the one hand and the effects of the hot environment on the other. This objective is extremely complex however, because there are so many aspects to occupational health hazards. Furthermore, the question of occupational effects is beyond the scope of this study. Therefore, the approach taken was to study the environmental impact of heat stress from a physiological perspective.

The logic behind this approach is as follows: If work in a hot environment presents a health hazard then the physiological systems which respond to the heat stress should be adversely affected. Since work in a hot environment posses a strain on the thermoregulatory mechanisms, the question is narrowed down even further. Will the strain posed by work in a hot environment for a major part of the year, be such that it would result in disorders of the systems participating in thermoregulation? The systems most specifically studied were the urogenitial and the cardiovascular systems. The urogenitial system has been shown to play a major role in the water and electrolyte balance when man is exposed to a hot environment (14,27,28,40,78). The cardiovascular system has the major role in heat dissipation (79,82,84) and has been considered by several investigators (19,61,84,93,111,115) to be the main "limiting-factor" to work in a hot environment.

METHODS

The study was conducted on the employees of a plant located in Sdom ("Sdom") and a plant in the Beer Sheva area ("Beer Sheva"). The plant at Sdom employs 769 employees and the one in Beer Sheva 114.

I. Studies of a normal work shift:

A. Ergonomic and physiological studies:

Ergonomic and physiological studies were conducted on healthy male workers of the metal work shop of the two plants. The studies were conducted during a normal work shift (0700-1500) in the metal work shop of the plants in mid-winter (Dec. 1977-Feb. 1978) and in mid-summer (June-August 1978). In Sdom 36 workers were studied in summer and 31 in winter, while the study in Beer Sheva included 13 and 16 workers respectively. Most of the workers observed participated in the study in both seasons.

Prior to the studies, the procedures were explained to the participants. It was emphasized to the participants that during the study they should go about their routine as in a normal work shift and try to ignore the presence of the investigator. Two workers were studied during each work shift.

1. Thermal measurements at the work area:

At the beginning and end of the work shifts in summer and winter in the metal work shop of the two plants the following variables were measured:

a. Dry bulb temperature (DB).
b. Wet bulb temperature (WB).
c. Globe temperature (GT) (C.F. Casella & Co. Ltd., London, T6454).

These measurements were also taken in both plants every hour during at least one work shift in summer and winter.

The dry and wet bulb temperatures were measured using a whirling psychrometer (C.F. Casella & Co. Ltd. London). The distilled water was daily replaced and the muslin wick was frequently changed. Relative humidity was determined by the depression of the wet bulb from a relative humidity table (C.F. Casella & Co. Ltd., London).

The indoor application of the wet bulb globe temperature index (WBGT) was calculated according to Yaglou and Minard (26) in the following manner:

$$WBGT = (0.7)WB + (0.3)GT$$

WB = wet bulb temperature

GT = globe temperature

2. Procedures in the plant clinic:

The worker reported to the plant clinic after changing into his normal work clothes and before commencing his daily work. The worker's age and duration of employment (seniority) were noted. The following were performed before and after the work shift:

a. A urine sample was obtained from the worker.

b. A venous blood sample (20 ml) was taken by a male nurse of the plant in the seated position.

c. The worker was weighed on a balance with an accuracy of 50 g. (Herbert and Sons Ltd., Edmonton).

d. The worker's height was measured (only before the work shift).

e. Blood pressure was measured in the seated position after at least 15 min rest.

In addition to the above, the following were installed at the beginning of each work shift:

a. A portable E.C.G. recorder (Medilog, Oxford Instruments Ltd.), which weighs about 400 g., was secured to the worker's belt on the right side in such a way as not to hinder his activities. Surface E.C.G. electrodes (Narco Bio-Systems Inc., # 710-0010) were taped to the skin on the left side on the clavicle and another to the skin on the right lower eleventh rib. Prior to securing the electrodes the skin was thoroughly cleaned with alcohol and allowed to dry.
b. Disc-type YSI thermistors (Yellow Spring Co. Model No. 409) were placed on the right upper arm, right chest, right thigh and when recording one was placed on the forehead. The thermistors were secured on the cleaned surface of the skin by taping (Micropore, Surgical Tape, 3M Company, No. 1530) with minimal area covered. The skin thermistors were secured under the normal work clothing of the worker and the wires (leads) were run under the clothing and secured to his belt. At the end of the work shift the worker returned to the clinic where the E.C.G. recorder was disconnected and all the electrodes and thermistors were removed before the worker was weighed.

3. Physiological variables measured during the work shift:

a) Heart rate: Heart rate was continuously recorded by the portable E.C.G. recorder on a magnetic cassette tape which was later analyzed on the Medilog ECG Analysis System (Oxford Instruments Ltd.).

b) Blood pressure: Blood pressure was measured by the ausculatory method using a sphygmomanometer (Taylor Nx. 101492) and stetescope (Lipman). Blood pressure was measured several times during the work shift in the sitting position and at least twice each time. The time and condition (work or rest) in each instance was noted. Blood pressure was measured under the following conditions:

a. After at least 15 min rest in the clinic before and after the work shift.

b. After at least 5 min rest (after a work bout) in the work area during the work shift.

c. Directly after a work bout of at least 5 min.

c) Body temperatures:

1) Oral temperature: Oral temperature was measured by an oral thermometer (FUAB 1111), which had an accuracy of 0.1°C. The oral thermometer was calibrated against a certified mercury thermometer. The oral thermometer was kept in the mouth for at least 5 min. Between measurements the oral thermometer was kept in alcohol.

2) Skin temperatures: Skin temperatures were measured with the disc-type YSI thermistors placed on the right upper arm, right chest, right thigh and the forehead. Skin temperatures were read on a tele-thermometer (Yellow Spring Co. Model No. 46 TUC), which had an accuracy of 0.1°C (calibrated against a certified mercury thermometer). After recording the skin temperatures, the leads were disconnected from the tele-thermometer and secured to the worker's belt.

Oral temperatures were measured while skin temperatures were recorded. Oral and skin temperatures were measured three times during each work shift:

a. Before commencing work in the clinic.

b. Before the lunch break in the work area.

c. At the end of the work shift in the work area.

d) Oxygen consumption: Whenever possible, the oxygen consumption of different typical tasks during the work shifts were measured. Expired gases were collected for two minutes in meteorological balloons. A sample (2 liters) was passed to a heavy walled rubber balloon after the volume (Wright Respirometer, E7017) and temperature was recorded. It was previously determined that the thick walled rubber balloon prevented diffusion of O_2 as well as CO_2 for as long as 36 hours. The O_2 and CO_2 analysis were performed the same day at the laboratory in Beer Sheva. CO_2 concentrations were measured by the absorption of infrared rays (Capnograph Godart Type CG 119). O_2 concentrations were measured by the paramagnetic method (Beckman Oxygen Analyzer Model E-2). All gas volumes were standardized to STPD (standard temperature and pressure, dry; 0^oC, 760 mmHg, 0% relative humidity). Oxygen consumption was calculated according to the procedure outlined by Consolazio et al (25).

4. Analysis of the E.C.G. recording:

a) Heart rate profiles during the work shifts: With the aid of the Medilog ECG Analysis System a recording of the heart rate during the work shift was obtained. The recording was analyzed in the following manner: The heart rate was catagorized into six groups; < 60, 60-80, 80-100, 100-120, 120-150 and > 150 beats/min. The amount of time that the heart rate of the worker was in each of these groups was determined and expressed as the per cent of the whole work shift.

b) Heart rate at the time that the blood pressure was measured: When the blood pressure was measured the time was noted. The Medilog ECG Analysis System enabled to estimate the heart rate at the time of the blood pressure measurement. The mean heart rate was determined by taking the heart rate a minute before, during and a minute after the blood pressure measurement.

5. Calculations of body temperatures:

a) Weighted mean skin temperature ($\bar{T}_s$): Weighted mean skin temperature was determined by a modification of the Hardy-Dubois method (42) in the following manner:

$$\bar{T}_s = (0.07)\text{forehead} + (0.19)\text{arm} + (0.36)\text{chest} + (0.38)\text{thigh}$$

b) Mean body temperature ($\bar{T}_B$): Mean body temperature was calculated according to Burton (20) in the following manner:

$$\bar{T}_B = (0.7)T_{oral} + (0.3)\bar{T}_s$$

T_{oral} = oral temperature

c) Body heat storage (S): Body heat storage was also calculated according to Burton (20) in the following manner:

$$S = (0.83)\ (\Delta\ \bar{T}_B)\ (B.W.)$$

0.83 = the specific heat of the body (cal/g.°C)

$\Delta\ \bar{T}_B$ = the change in the mean body temperature

B.W. = body mass (Kg.)

S is expressed in Kcal/hour.

B. Blood and urine studies:

1. Treatment of blood and urine samples:

a) Blood: Approximately 2.5 ml of whole blood was transferred to a specially treated test tube containing 3.75 mg K.-EDTA (for hemoglobin and hematocrite determinations). The remaining blood sample was transferred to a glass centrifuge test tube and allowed to stand for about 15 min till serum was formed and then centrifugated for 10 min. The serum was then transferred to several other test tubes and frozen.

b) Urine: A few crystals of thymol were added to the urine sample in order to avoid bacterial growth.

The blood, serum and urine samples were transported to the laboratory in Beer Sheva under refrigeration. The sera and urines were kept frozen until just prior to analysis.

2. Blood and urine chemical analysis:

Within 5 min after the urine was passed (before the thymol crystals were added) it was checked for glucose, protein, occult blood and pH by reagent strips for urinanalysis (Hema-Combistix, Ames Company, England). The reagent glucose test is specific for glucose and as little as 1 g/l is detectable. As little as 0.05 g/l of albumin may be detected by the protein test. The occult blood test has a sensitivity to free hemoglobin of 1.5×10^{-4} g/l or 5-10 intact red blood cells/ul urine with a specific gravity of 1.005. The pH test permitted quantitative differentiation of pH values to one unit within the range of 5-9. pH was also determined by pH paper (Whatman-DBH, England), which permitted differentiation of pH values to one half unit within the range of 4-9.

Hemoglobin and hematocrite were determined the same day. Hemoglobin was determined according to the cyanmethemglobin method (31). The accuracy of the determination was 0.2 g. Hematocrite was determined by using heparinized capillary tubes (Propper, New York) and centrifugation of 10 min (Adams Autocrit Centrifuge). Hemoglobin and hematocrite were determined at least in duplicates.

Urea, creatinine, uric acid, sodium and potassium determinations were performed at the Nephrology Laboratory of the Soroka Medical Center, on the Auto Analyzer (Technicon). Urea was determined by a modification of the oxime method (64). Creatinine was performed by a modified method of Folin and Wu (22). Uric acid was determined by a modification of the phosphotungstate method (102). Sodium and potassium were determined by the flame photometry method as described in (95).

Urine and serum osmolality were determined by the cryoscopic method. Urine osmolality was determined on the Advanced Osmometer (Advanced Instruments, Inc. Model 31 LAS) using a 2 ml urine sample. Serum osmolality was determined on the Fiske Osmometer (Model OM) using a 0.25 ml serum sample. The osmolality determinations were performed at least in duplicates.

The total protein serum concentrations were determined by the Biuret method (107). Albumin was determined with Bromcresol Green (Sigma Chemical Co.). Globulin was determined as the difference between the total protein and albumin. Total protein and albumin were performed in triplicates.

The accuracy of the determinations were as follows: Urea 0.5 mg%, creatinine and uric acid 0.05 mg%, sodium 1 mEq/1, potassium 0.1 mEq/1, total protein and albumin 0.2 g., urine osmolality 5 mOsm/Kg., and serum osmolality 2 mOsm/Kg.

3. Calculations of changes in volumes of blood, plasma and red blood cells:

The percentage changes in volumes of blood, plasma and red blood cells were calculated from the hemoglobin and hematocrite (no correction for trapped plasma was made) values before and after the work shift, according to the formulas derived by Dill and Costill (29) in the following manner:

BV_B was taken as 100

$BV_A = BV_B \, (Hgb_B/Hgb_A)$

$CV_A = BV_A \, (Hct_A)$

$PV_A = BV_A - CV_A$

Δ BV, % = $100 \, (BV_A - BV_B)/BV_B$

Δ CV, % = $100 \, (CV_A - CV_B)/CV_B$

Δ PV, % = $100 \, (PV_A - PV_B)/PV_B$

The subscripts B and A refer to before and after the work shift respectively.

Hgb = hemoglobin concentration

Hct = hematocrite

BV = blood volume

CV = red blood cell volume

PV = plasma volume

4. Calculation of renal water reabsorption:

The per cent renal water reabsorption was estimated as follows:

$$\text{\% renal water reabsorption} = \left(1 - \left(\frac{1}{\text{U/S creatinine}}\right)\right)(100)$$

U/S creatinine denotes the urine to serum creatinine ratio.

5. <u>Estimation of urine volume during the work shift</u>:

The urine volume during the work shift was estimated as follows:

$$U_v = \frac{GFR}{U/S \text{ creatinine}} = \frac{UV/S}{U/S \text{ creatinine}}$$

U_v = estimated urine volume during the work shift.

GFR = glomerular filtration rate. It was assumed that the GFR was normal and was taken as 125 ml/min as determined by creatinine clearance measurements (9).

The U/S creatinine ratio was taken as the arithmetic mean before and after the work shift.

U = creatinine concentration in the urine.

V = volume of the urine.

S = creatinine concentration in the serum.

6. <u>Hormonal analysis</u>:

a) <u>Aldosterone</u>: Aldosterone serum levels were determined quantitatively by the radioimmunoassay method using the C.I.S. (CEA IRE SORIN) Aldosterone Radioimmunoassay Kit (Laboratoire des Products Biomedicaux, France). The analytical sensitivity (Lowest detectable dose) was 3.5 ± 0.5 pg.

b) <u>Cortisol</u>: Cortisol serum levels were determined quantitatively by the radioimmunoassay method outlined by the Miles-Yeda Ltd. (Kiryat Weizmann, Rehovot, Israel) from whom the Anti-Cortisol-21-Thyroglobulin antiserum was purchased. The sensitivity was such that 5 pg of cortisol/tube could be detected.

c) <u>Thyroxine (T-4)</u>: Total thyroxine (bound and from T-4) in serum was determined by the Murphy-Pattee competitive binding principle using the Tetralute Reagent Kit for Thyroxine (Ames-Yissum Ltd., Division Miles Laboratories, Inc.). The test is reported to be specific for thyroxine.

d) <u>Triiodothyronine (T-3)</u>: Total triiodothyronine serum levels were determined quantitatively by the radioimmunoassay method, using the Seralute Total T-3 Radioimmunoassay Kit (Ames-Yissum Ltd., Division Miles Laboratories, Inc.). The minimum amounts of T-3 which could be detected by the Seralute Total T-3 (RIA) test was stated to be 50 ng/100 ml. The cross reactivity of the T-3 antiserum to thyroxine was stated to be less than 0.19%. All hormonal determinations were performed at least in duplicates. Results were only considered when the inter and intra assay coefficient of variance was less than 10%.

C. <u>Statistical analysis</u>:

The statistical analysis was performed using programs of the SPSS (Statistical Package for Social Sciences). Differences were considered statistically significant only if $P \leq 0.05$. The physiological reactions during the work shifts were compared in the following manner: Summer and winter comparisons were performed on only those workers who were studied in both seasons. This comparison was performed on each plant separately. Thus each worker served as his own control. Basically this was a comparison of reactions during a work shift in a comfortable and warm environment. A comparison was also performed between the workers of the two plants, each season separately, on all the workers studied. The comparison in winter was of reactions during the

work shifts in a comfortable environment. The one in summer was to compare the reactions in warm and hot environments. The blood and urine variables were also compared to accepted normal ranges.

II. Survey of cardiovascular and urogenitial disorders:

A. Certificates of illness:

All the certificates of illness stored in the archives of the plants were collected for each employee from January 1st 1971 to December 31, 1976. The incidences of the following disorders were determined from these certificates:

a. Diseases of the cardiovascular system, i.e., functional heart diseases, arterioscleratic and degenerative heart diseases.

b. Coronary diseases.

c. Hypertensive diseases.

d. Diseases of the urogenitial system.

B. Electrocardiogram and blood pressure examinations:

A representative group of workers including about half the workers of the plants underwent electrocardiogram and blood pressure examinations during rest (at least 15 min) in the plant clinic. The medical analysis of these examinations were performed by the physicians of the Occupational Health Department in Beer Sheva. In cases were abnormally high blood pressure (systolic higher than 160 mmHg and or diastolic higher than 95 mmHg) were measured, the employees were asked to report to the clinic in the plant as well as at their place of residence

(Arad, Beer Sheva or Dimona) for several days of repetitive measurements. Workers were diagnosed as hypertensive if their blood pressures were consistently found to be abnormally high both at work and at home. All the pathological cases were compared with the employee's medical file of his family physician by members of the Occupational Health Department. In cases of doubt, the employee underwent an extensive medical examination by the physician of the Occupational Health Department in Beer Sheva as well as in the plant.

C. Analysis of the survey:

The employees in Sdom were divided into two groups. Those who were exposed to the hot environment (during the warm season) for a major part of their work shifts were classified as "heat exposed" while the rest as "unexposed". They were further divided randomly into two age subgroups: younger than 46 and those who were 46 and older. The same was done concerning the seniority. The groups here consisted of those with less than 11 and those with 11 and more years. The per cent of the heat exposed workers differed from those of the unexposed within the age and seniority subgroups. In order to perform a valid comparison of the contribution of the heat exposed and unexposed to the subgroup who suffered from cardiovascular and urogenitial disorders, their contribution was "adjusted" as the following example illustrates: If 55% of all the employees of the plant were younger than 46 and were heat exposed, while only 22% of this age were unexposed, then the per cent contribution of the latter subgroup to the group which suffered from cardiovascular and orogenitial disorders was multiplied by 2.5.

RESULTS

The characteristics of the workers studied during the work shifts are presented in Tables 1A, B. They were similar in both seasons (Table 1A) as well as in both plants (Table 1B).

TABLE 1A. Comparison of the characteristics of the workers studied during the work shifts in Summer and Winter

Plant	Season	n (No. of workers)	Age (yr)	Seniority (yr)	Weight (kg)	Height (cm)	Body surface area (m^2)
Sdom	Summer	25	*38.0	13.0	74.0	172.1	1.9
			**(10.8)	(8.2)	(9.1)	(7.3)	(0.1)
	Winter	25	37.5	12.5	74.4	171.2	1.9
			(10.8)	(8.3)	(9.1)	(6.8)	(0.1)
Beer Sheva	Summer	9	41.0	14.0	68.7	169.6	1.8
			(11.5)	(6.8)	(14.8)	(7.2)	(0.2)
	Winter	9	40.5	13.5	69.4	168.6	1.8
			(11.5)	(6.8)	(15.1)	(8.4)	(0.2)

* Mean

** Standard deviation

TABLE 1B. A comparison of the characteristics of the workers studied during the work shifts in Sdom and Beer Sheva

Season	Plant	n (No. of workers)	Age (yr)	Seniority (yr)	Weight (kg)	Height (cm)	Body surface area (m^2)
Summer	Sdom	36	*37.5	11.1	75.0	172.8	1.9
			**(10.9)	(8.8)	(9.3)	(6.3)	(0.1)
	Beer Sheva	13	38.4	12.1	69.7	170.4	1.8
			(12.2)	(9.0)	(13.2)	(6.0)	(0.2)
Winter	Sdom	31	38.8	13.2	75.5	171.3	1.9
			(11.7)	(8.7)	(9.9)	(6.3)	(0.1)
	Beer Sheva	16	37.9	12.4	67.5	171.2	1.7
			(12.1)	(8.7)	(21.2)	(7.3)	(0.5)

* Mean

** Standard deviation.

I. Studies of a normal work shift:

A. Thermal environment:

The workers of Sdom were exposed to higher environmental temperatures and lower relative humidity during the year than those of Beer Sheva (Tables 2,3). This was particularly amplified during the summer months. The WBGT at the work area was slightly higher in Sdom in winter, but in summer the difference was greater (Table 4). The WBGT in summer in Sdom complied to the defination of NIOSH for a hot environment and approached the recommended upper limit for

continuous light to moderate work set by the American Conference of Governmental Industrial Hygienist. A profile of the WBGT during a work shift (Fig 1) shows that a major part of the work shift in Sdom in summer was above the definition of a hot environment set by NIOSH.

TABLE 2. Temperature and relative humidity recorded over a ten year period by the Meteorological Service of Israel*.

	Average daily Temperature (°C)		Average daily Relative Humidity (%)		Average monthly maximum Temperature (°C)		Average monthly minimum Temperature (°C)		Average daily range of Temperature (°C)	
Plant	Sdom	Beer Sheva	Sdom	Beer Sheva	Sdom	Beer Sheva	Sdom	Beer Sheva	Sdom	Beer Sheva
Month										
I	15.8	11.6	56	70	25.0	23.5	6.9	1.8	9.9	10.8
II	17.0	12.4	50	67	27.0	26.5	7.1	2.1	10.9	12.1
III	19.7	14.0	46	62	32.2	30.9	9.0	2.5	11.4	12.0
IV	24.0	17.9	38	56	38.6	35.8	11.8	4.6	12.6	14.4
V	28.5	22.8	35	48	42.7	39.0	16.6	9.0	13.2	15.5
VI	31.6	24.6	34	48	43.0	38.4	21.3	[illegible]	14.0	15.3
VII	33.6	26.2	33	52	45.0	37.9	23.7	14.8	13.9	14.8
VIII	33.8	26.0	35	56	44.1	37.7	24.3	15.1	13.3	15.3
IX	31.4	24.2	40	58	41.2	36.4	21.9	13.0	11.6	14.6
X	27.6	22.0	42	55	38.7	36.2	17.8	9.9	11.1	14.8
XI	22.5	18.5	49	60	32.7	31.7	12.6	6.4	10.6	13.0
XII	17.6	13.5	57	68	26.7	26.4	8.3	3.2	9.8	11.0
Year	25.3	19.5	43	58					11.9	13.6

* Climatological normals part one B. Temperature and relative humidity (2^{nd} edition). State of Israel, Ministry of Transport and Communications, Meteorological Service series A (Meteorological Notes) No. 3B Tel-Aviv 1961. Published by the Meteorological service of the State of Israel Printed by the Government Press, Hakirya.

TABLE 3. Temperature and relative humidity recorded at 0800 and 1400 over a ten year period by the Meteorological Service of Israel.

	Average Temperature (°C)				Average Relative Humidity (%)			
Plant	Sdom		Beer Sheva		Sdom		Beer Sheva	
Time	0800	1400	0800	1400	0800	1400	0800	1400
Month								
I	12.9	20.0	9.1	16.3	66	45	74	58
II	14.4	21.4	9.6	17.4	60	38	66	51
III	17.7	24.0	12.6	19.2	56	35	59	45
IV	22.6	28.8	17.0	24.2	49	29	64	40
V	27.1	33.2	22.1	29.4	45	26	62	35
VI	30.1	36.5	24.3	31.2	44	26	58	31
VII	31.8	38.5	25.4	32.6	43	24	53	36
VIII	32.1	38.4	25.5	32.8	45	26	52	38
IX	30.2	35.4	23.8	30.5	49	31	61	42
X	26.5	32.1	21.6	28.4	50	34	70	40
XI	20.5	27.0	16.7	24.1	57	39	74	45
XII	14.8	21.8	11.2	18.2	66	47	77	52
Year	23.4	29.8	18.2	25.4	52	33	64	43

TABLE 4. Temperature and relative humidity recorded at the work site before and after the work shift.

Plant	Sdom				Beer Sheva			
Season	Summer		Winter		Summer		Winter	
Time	Before[6]	After[7]	Before	After	Before	After	Before	After
Variable								
D.B.[1]	*33.45	40.28	14.37	20.06	26.61	32.89	12.77	19.27
(°C)	**(1.79)	(2.34)	(2.50)	(1.82)	(1.19)	(2.26)	(1.84)	(3.55)
W.B.[2]	21.84	22.89	9.90	12.78	21.61	21.50	8.32	10.91
(°C)	(1.21)	(1.06)	(1.77)	(1.58)	(1.45)	(1.97)	(1.40)	(2.96)
G.T.[3]	34.17	41.42	14.43	20.47	28.56	34.28	14.09	19.64
(°C)	(1.77)	(2.38)	(2.51)	(1.73)	(1.38)	(2.37)	(1.84)	(3.44)
W.B.G.T.[4]	25.54	28.45	11.29	15.13	23.69	25.33	10.07	13.55
(°C)	(1.05)	(1.16)	(1.96)	(1.45)	(1.38)	(2.01)	(1.24)	(2.90)
R.H.[5]	36.17	22.22	57.07	43.08	64.67	36.22	55.64	34.55
(%)	(6.89)	(4.45)	(8.29)	(9.56)	(8.20)	(4.76)	(14.63)	(13.00)

1 Dry bulb temperature

2 Psychrometric wet bulb temperature

3 Globe temperature

4 Wet bulb globe temperature = (0.7) WB + (0.3) GT

5 Relative humidity, by depression of wet bulb

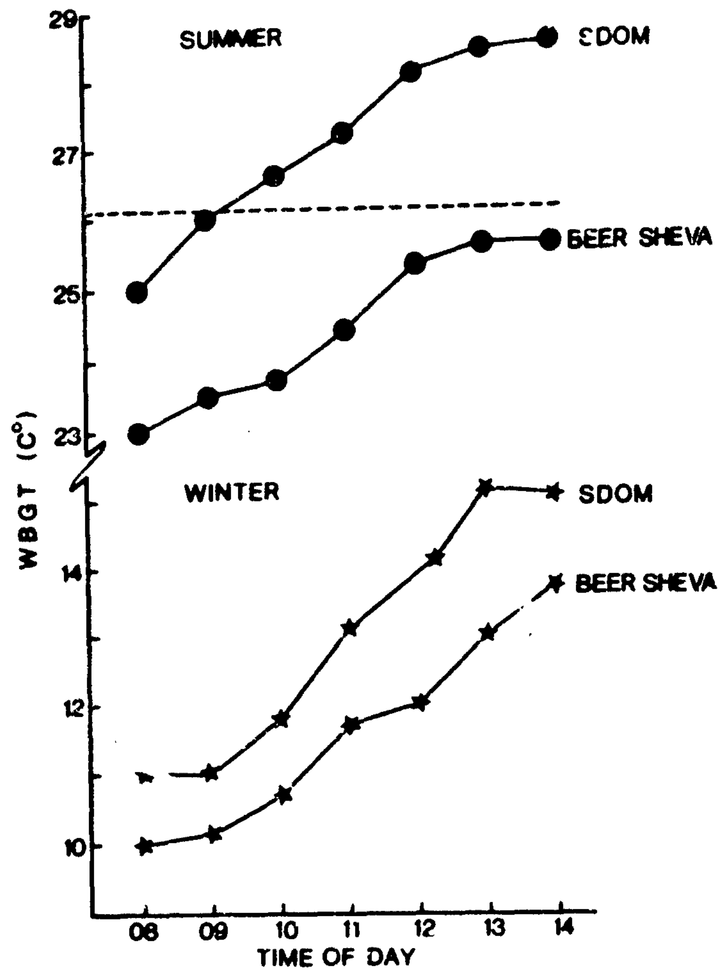
6 Before work, ∿ 0800 A.M.

7 After work, ∿ 1400 P.M.

* Mean

** Standard deviation.

Fig. 1. Wet Bulb-Globe Temperature profiles in the metal work shops during a work shift in summer and winter.



Wet Bulb-Globe Temperature (WBGT) index values above the dotted line (WBGT = 26.2^{0}C) defines a hot environment for light to moderate work as recommended by NIOSH (26).

B. Ergonomic and physiological studies:

1. Oxygen consumption:

The mean oxygen consumption measured of typical tasks performed during the work

shifts is presented in Table 5.

TABLE 5. The mean oxygen consumption measured of typical tasks performed during the work shift

Task	Mean oxygen consumption ($\dot{V}O_2$ (1/min)STPD*))
Welding	0.74
Welding and beating metal	0.95
Hammering (light)	0.70
Hammering (heavy)	0.90
Hammering (very heavy)	1.30
Hammering with chizel	0.88
Soldering	0.60
Filling (light)	0.60
Filling (heavy)	0.80
Cutting metal on machine	0.97
Drilling	0.70
Scratching old paint	0.61
Cutting fiberglass	0.80
Preparing fiberglass	1.10
Tightening screws (light)	0.60
Tightening screws (heavy)	0.90
Unscrewing screws	0.88
Unscrewing pipes	0.92
Greasing	0.90
Walking	0.55
Walking carrying objects (light)	0.80
Walking carrying objects (heavy)	1.40
Running	1.15
Riding in vehicle	0.45
Driving vehicle	0.55
Rest (sitting)	0.45

*STPD standard temperature and pressure, Dry (0^oC, 760 mm Hg, 0% relative humidity).

2. Heading rate:

The heart rate profiles of the work shifts in Sdom were found to be similar in the two seasons while in Beer Sheva they were not (Fig. 2). The values of 100 beats/min and higher were found to be higher in winter than in summer in Beer Sheva. Comparing the heart rate profiles between Sdom and Beer Sheva, it was observed that they were similar in summer but in winter they were slightly higher in Beer Sheva (Fig. 3).

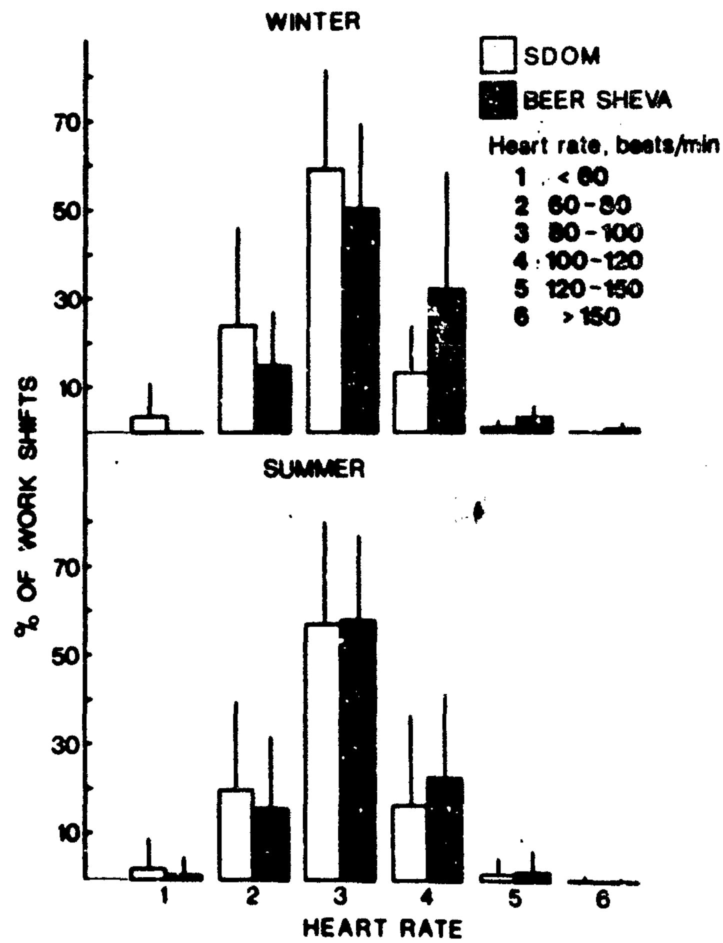
When the work shift was divided into two, it was observed that the heart rates were significantly higher in winter than in summer during the first part of the work shifts in both plants (Fig. 4). During the second part of the work shifts, no differences were found between the seasons in Sdom, while in Beer Sheva, the heart rate was higher in winter (Fig. 4).

In summer, there were no significant differences between the heart rate profiles of the two plants during the two parts of the work shifts. In winter, on the other hand, the heart rate profiles were found to be higher in Beer Sheva in the first part of the work shifts (Fig. 5).

It was observed that regardless of the season or the plant the heart rates were between 80-100 beats/min during a greater part of the work shifts (Figures 2,3,4,5).

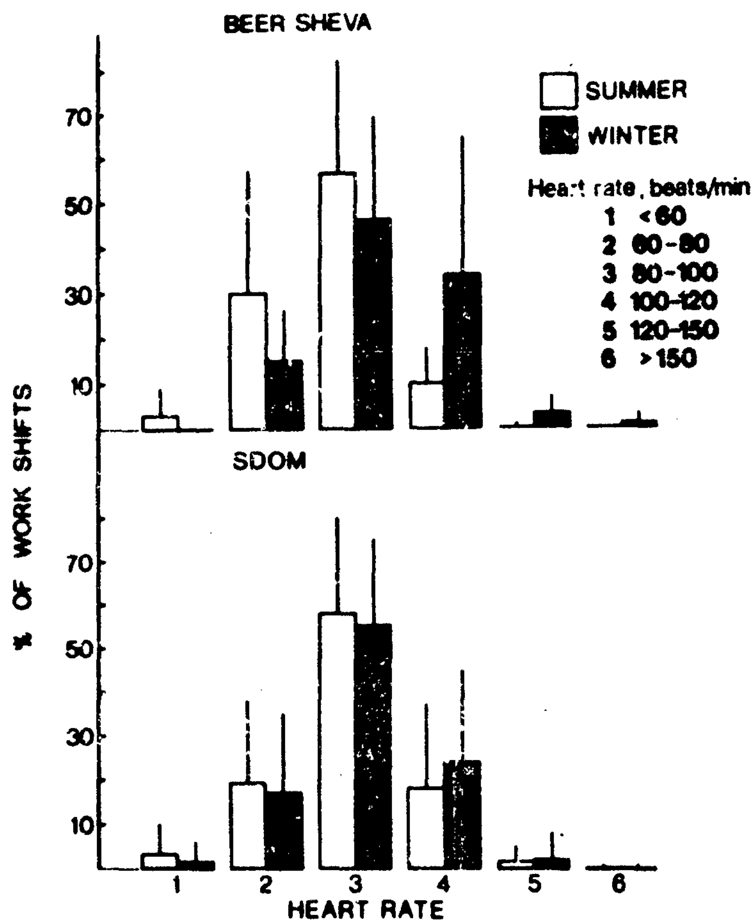
The heart rate profiles of outdoor maintenance workers in Sdom performing urgent work in summer were different than those of the workers of the metal work shop (Fig. 6). Their heart rate profiles show that during more than 40% of their work shifts the heart rate was above 120 beats/min. Other workers of this department who were engaged in non-urgent work had heart rate profiles resembling those of the metal work shop workers (Fig. 6).

Fig. 2. Heart rate profiles of the metal work shop workers during the work shifts in summer and winter.



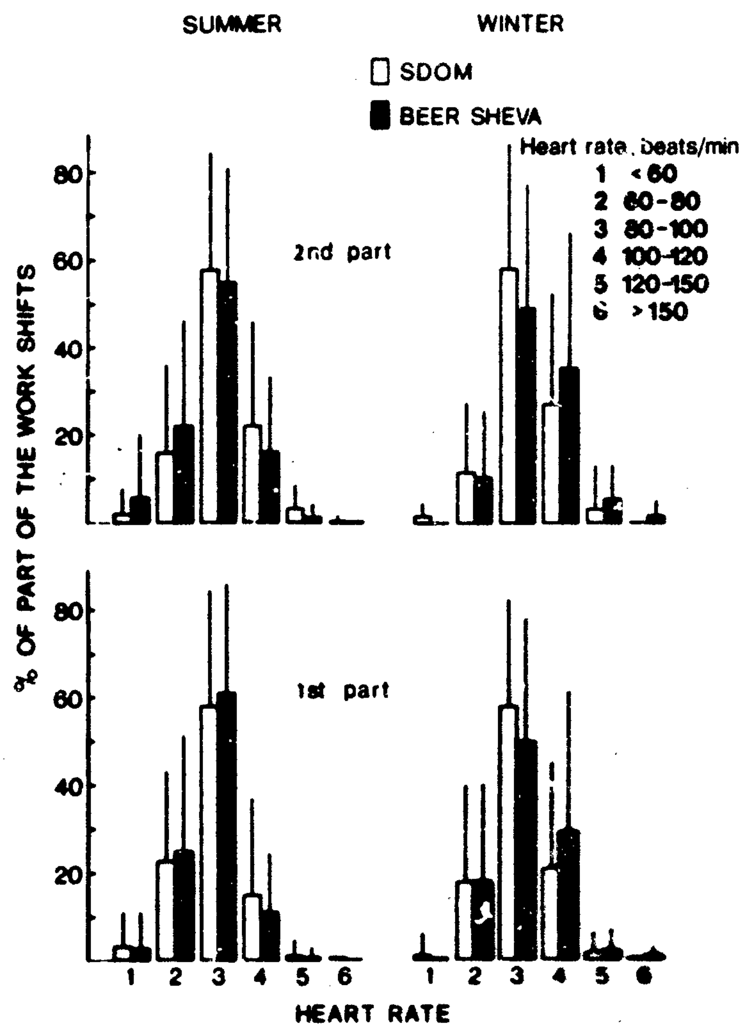
The heart rate of 24 workers was recorded both in summer and winter in Sdom and of 7 workers in Beer Sheva. Vertical lines denotes standard deviation.

Fig. 3. Heart rate profiles of the metal work shop workers during the work shifts in Sdom and Beer Sheva.



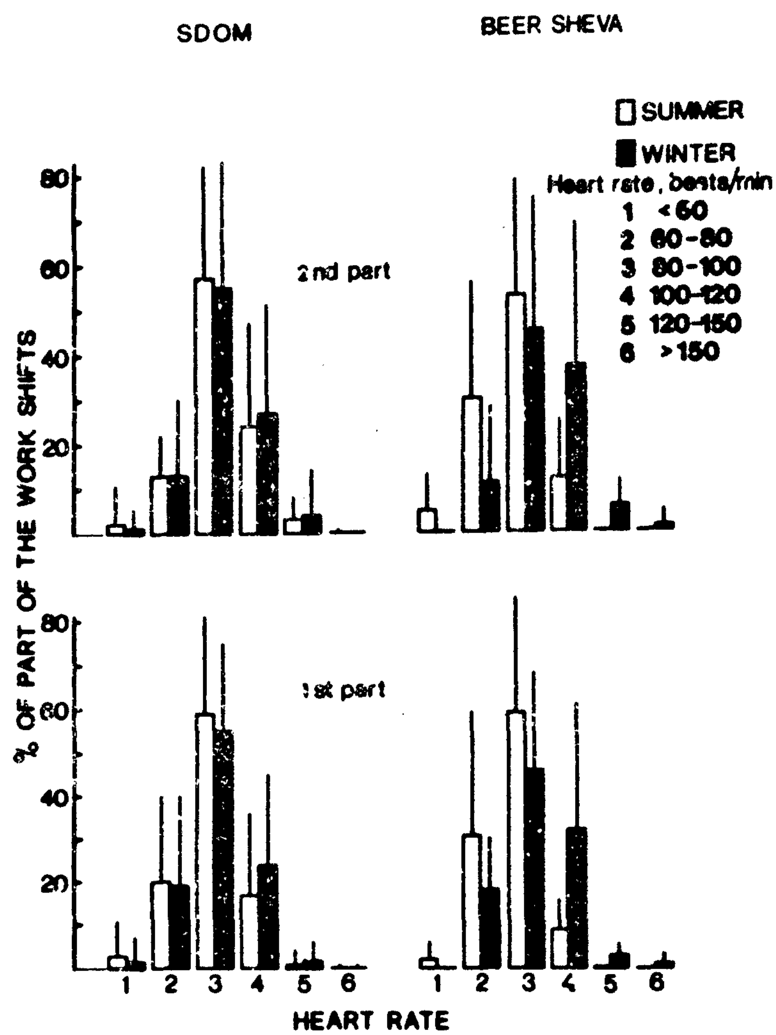
The heart rate of 35 workers was recorded in summer and of 31 in winter in Sdom and of 13 and 12 in Beer Sheva. Vertical lines denote standard deviation.

Fig. 4. Heart rate profiles of the metal work shop workers during the two parts of the work shifts in summer and winter.



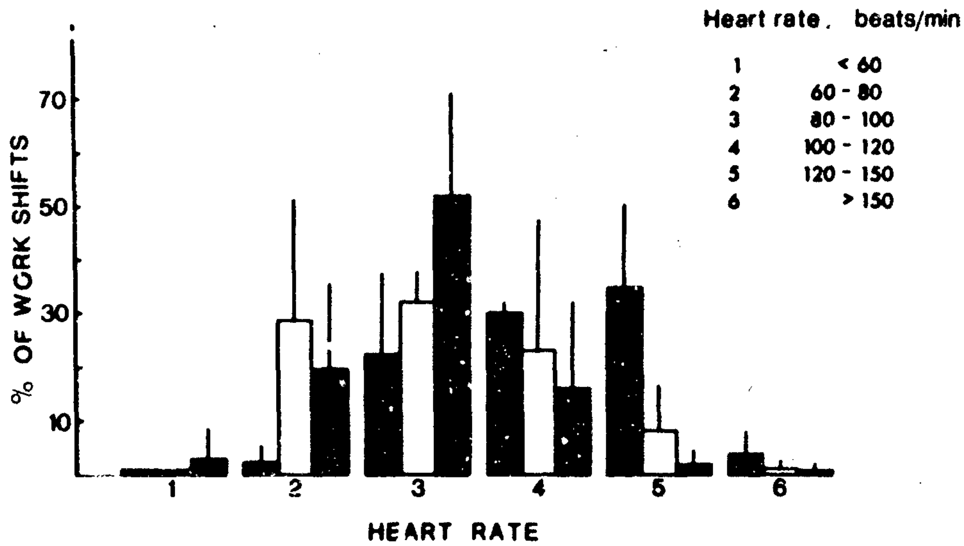
The heart rate of 24 workers was recorded in summer as well as in winter in Sdom and of 7 in Beer Sheva. Vertical lines denotes standard deviation.

Fig. 5. Heart rate profiles of the metal work shop workers during the two parts of the work shifts in Sdom and Beer Sheva.



The heart rate of 35 workers was recorded in summer and of 31 in winter in Sdom and of 13 and 12 in Beer Sheva. Vertical lines denotes standard deviation.

Fig. 6. Heart rate profiles during summer work shifts in Sdom of outdoor maintenance workers and of workers of the metal work shop.



Full bars are of 3 outdoor maintenance workers who performed emergency work.

Empty bars are of 3 outdoor maintenance workers who performed non-urgent (regular) work.

Dotted bars are of 35 metal work shop workers.

Vertical lines denotes standard deviation.

3. Body temperatures and thermal evaluations:

The body heat storage was significantly higher in summer than in winter in Sdom and especially so during the first part of the work shifts (Table 6A). This resulted from the higher skin temperatures during the work shifts in summer. In fact, skin temperatures approached 36°C during the work shifts in summer in Sdom. In Beer Sheva, on the other hand, the body heat storage was significantly higher in winter and especially so in the first part of the work shifts (Table 6A). This resulted from the higher increase in oral temperatures in winter. Before the work shifts, the weighted mean skin temperatures were lower in summer than in winter in Sdom (Table 6A). In Beer Sheva, on the other hand, the weighted mean skin temperatures, oral and mean body temperatures were higher in summer than in winter (Table 6A).

In both plants the mean weighted skin temperatures as well as the mean body temperatures during the work shifts were significantly higher in summer than winter with no differences in the oral temperatures (Table 6A).

Comparing the workers of the two plants; the body heat storages were much higher in Sdom in summer than in Beer Sheva. This resulted from the higher skin temperatures in Sdom (Table 6B). In winter, the body heat storage was higher in Beer Sheva than in Sdom. This resulted from the higher increase in skin and oral temperatures during the work shifts in Beer Sheva than in Sdom (Table 6B).

Before the work shifts, the weighted mean skin temperatures and mean body temperatures were higher in Beer Sheva than in Sdom in summer (Table 6B). In winter, the opposite was observed, they were higher in Sdom (Table 6B).

In summer, the weighted mean skin temperatures and mean body temperatures were significantly higher in Sdom than in Beer Sheva with no differences in the oral temperatures (Table 6B). In winter they were similar.

TABLE 6A. Body temperatures, body heat storage and weight recorded during the work shift: Summer and Winter.

Time	Plant	Season	n	Mean weighed skin temperature $\bar{T}s$ (°C) X	S.D.	Oral temperature Toral (°C) X	S.D.	Mean body temperature $\bar{T}_B$ (°C) X	S.D.	Body heat storage (Kcal/hr) X	S.D.	Weight (Kg) X	S.D.
Before work shift in clinic	Sdom	Summer	25	31.9 [a]	(0.7)	36.8	(0.3)	35.4	(0.3)			74.0	(9.1)
		Winter	25	32.5	(0.7)	36.8	(0.2)	35.5	(0.3)			74.4	(9.1)
	Beer Sheva	Summer	9	33.4 [a]	(0.3)	37.0	(0.2)	35.9 [a]	(0.2)			68.7	(14.8)
		Winter	9	31.4	(0.8)	36.6	(0.4)	35.0	(0.3)			69.4	(15.1)
1st part of work shift	Sdom	Summer	25	35.2 [a]	(0.7)	37.0	(0.3)	36.4 [a]	(0.3)	18.0[(1)] [a]	(5.8)		
		Winter	25	33.1	(0.9)	36.9	(0.3)	35.8	(0.3)	4.2	(5.2)		
	Beer Sheva	Summer	9	34.6 [a]	(0.4)	37.0	(0.2)	36.3	(0.2)	5.4	(2.2)		
		Winter	9	33.4	(1.0)	37.0	(0.2)	35.9	(0.3)	13.2	(7.4)		
2nd part of work shift	Sdom	Summer	25	35.8 [a]	(0.6)	37.2	(0.2)	36.7 [a]	(0.2)	8.0	(5.6)	74.1	(9.1)
		Winter	25	33.7	(0.7)	37.1	(0.3)	36.1	(0.3)	7.9	(5.9)	75.3	(8.7)
	Beer Sheva	Summer	9	34.9 [a]	(0.5)	37.2	(0.3)	36.5 [a]	(0.3)	3.9	(3.6)	68.0	(15.0)
		Winter	9	33.9	(1.2)	37.0	(0.2)	36.1	(0.4)	4.1	(5.1)	70.0	(15.8)

(TABLE 6A continued)

				ΔTs		ΔT_{oral}		ΔT_B				Δweight	
Whole work shift	Sdom	Summer	25	3.9	(0.8)	0.3	(0.2)	1.4	(0.3)	13.1	(3.8)	0.1	(9.1)
		Winter	25	1.2[a]	(0.7)	0.3	(0.2)	0.5[a]	(0.3)	5.5[a]	(2.8)	0.8	(9.2)
	Beer Sheva	Summer	9	1.5	(0.4)	0.2	(0.3)	0.6	(0.3)	4.5	(1.8)	0.7	(15.0)
		Winter	9	2.5[a]	(1.3)	0.4[a]	(0.4)	1.1[a]	(0.6)	8.5[a]	(5.0)	0.6[a]	(15.3)

(1) The mean weight (before and after work shift) was used to determine the body heat storage during the 1st part of the work shift.

X Mean

S.D. Standard deviation

a Statistically significant ($P \leq 0.05$) differences between summer and winter

Δ (after work shift)-(before work shift).

TABLE 6B. Body temperatures, body heat storage and weight recorded during the work shift: Sdom and Beer Sheva.

Time	Season	Plant	n	Mean weighed skin temperature Ts (°C)		Oral temperature Toral (°C)		Mean body temperature T_B(°C)		Body heat storage (Kcal/hr)		Weight (Kg)	
				X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.
Before work shift in clinic	Summer	Sdom	36	^{b}32.0	(0.8)	36.9	(0.3)	^{b}35.4	(0.3)			75.0	(9.2)
		Beer Sheva	13	^{b}33.3	(0.3)	37.0	(0.2)	^{b}35.9	(0.2)			69.6	(13.1)
	Winter	Sdom	31	^{b}32.5	(0.8)	36.8	(1.0)	^{b}35.5	(0.4)			75.4	(10.0)
		Beer Sheva	16	^{b}31.3	(0.9)	36.7	(0.4)	^{b}35.1	(0.3)			71.5	(12.6)
1st part of work shift	Summer	Sdom	36	^{b}35.2	(0.7)	37.0	(0.3)	^{b}36.5	(0.3)	^{b}18.0(1)	(5.6)		
		Beer Sheva	13	^{b}34.4	(0.6)	37.0	(0.1)	^{b}36.2	(0.2)	^{b}4.7	(2.2)		
	Winter	Sdom	31	33.2	(1.0)	36.9	(0.3)	35.6	(0.4)	^{b}5.0	(6.6)		
		Beer Sheva	16	32.4	(1.0)	37.0	(0.2)	35.9	(0.4)	^{b}13.1	(7.6)		
2nd part of work shift	Summer	Sdom	36	^{b}35.8	(0.6)	37.2	(0.2)	^{b}36.8	(0.3)	^{b}7.5	(5.3)	75.1	(9.2)
		Beer Sheva	13	^{b}34.7	(0.5)	37.2	(0.2)	^{b}36.4	(0.3)	^{b}4.1	(3.9)	69.1	(13.2)
	Winter	Sdom	31	33.7	(0.8)	37.1	(0.3)	36.1	(0.3)	7.1	(7.0)	76.3	(10.0)
		Beer Sheva	16	34.0	(1.1)	37.1	(0.2)	36.2	(0.4)	4.6	(4.3)	72.1	(12.7)

(TABLE 6B continued)

				ΔTs		ΔToral		ΔT_B				Δweight	
Whole work shift	Summer	Sdom	36	$^{b}3.8$	(0.8)	0.3	(0.2)	$^{b}1.4$	(0.3)	$^{b}12.9$	(3.4)	$^{b}0.1$	(0.6)
		Beer Sheva	13	$^{b}2.4$	(0.4)	0.2	(0.3)	$^{b}0.6$	(0.3)	$^{b}4.1$	(1.7)	$^{b}-0.4$	(1.4)
	Winter	Sdom	31	$^{b}1.3$	(0.7)	$^{b}0.3$	(0.2)	$^{b}0.6$	(0.3)	$^{b}5.8$	(3.3)	0.3	(0.6)
		Beer Sheva	16	$^{b}2.7$	(1.2)	$^{b}0.4$	(0.4)	$^{b}1.2$	(0.5)	$^{b}8.7$	(4.3)	0.1	(0.8)

(1) The mean weight (before and after work shift) was used to determine the body heat storage during the 1st part of the work shift.

X Mean

S.D. Standard deviation

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva

Δ (after work shift)-(before work shift).

4. Blood pressure:

In both plants the blood pressures measured at rest in the work area during the work shifts were lower in summer than in winter (Tables 7A, 8A).

The blood pressures measured immediately after work were lower in summer than in winter in Beer Sheva. In Sdom no differences were observed. The heart rates at the times when these blood pressures were measured were about 100 beats/min in both plants in both seasons (Tables 7A,8A).

The blood pressures measured during work and rest were higher in Sdom than in Beer Sheva only in summer (Tables 7B,8B).

The blood pressures measured during rest periods in the clinic before and after the work shifts, were lower in summer than in winter only in Beer Sheva (Table 7A). In summer there were differences in these conditions between Sdom and Beer Sheva. At that time, the blood pressures were higher in Sdom (Table 7B).

In both plants and in both seasons the blood pressures and heart rates were significantly higher during work than rest (Tables 9 (a), 10). In Beer Sheva in both seasons and in Sdom only in winter, there was an increase in systolic and pulse pressures. In Sdom in summer there was an increase in the diastolic pressure as well (Tables 9 (a), 10).

The differences in the blood pressures between the periods of rest and work during the work shifts in Sdom were greater in summer than in winter. This could be seen by the higher increase in systolic and diastolic pressures (Tables 9 (a), 10). In Beer Sheva the differences were greater in winter (Tables 9 (a), 10). In both plants in both seasons, the blood pressure measurements taken at rest in the clinic before and after the work shifts were observed to be similar (Table 9 (b)).

TABLE 7A. Blood pressure, pulse pressure and heart rate recorded during the work shift: Summer and Winter.

Conditions	Plant	Season	Number of measurements	Blood Pressure (mm Hg) Systolic		Diastolic		Pulse Pressure (mm Hg)		Heart Rate (beats/min)	
				X	S.D.	X	S.D.	X	S.D.	X	S.D.
Rest in air conditioned clinic, before work shift	Sdom	Summer	25	118	(8.5)	81	(6.6)	37	(8.1)	82	(12.3)
		Winter	25	119	(9.7)	81	(7.6)	38	(7.5)	83	(10.6)
	Beer Sheva	Summer	9	107	(8.7)	75	(6.1)	39	(8.7)	80	(10.8)
		Winter	9	120[a]	(12.0)	83[a]	(9.2)	37[a]	(5.8)	82	(16.2)
Rest in air conditioned clinic after work shift	Sdom	Summer	25	116	(6.8)	79	(6.2)	37	(7.7)	87	(11.0)
		Winter	25	118	(8.5)	80	(5.8)	38	(6.4)	88	(10.2)
	Beer Sheva	Summer	9	107	(7.5)	74	(8.3)	33	(5.4)	79	(9.7)
		Winter	9	116[a]	(10.1)	80	(7.4)	36	(6.7)	89	(11.6)
Rest in work area during work shift	Sdom	Summer	130	112	(7.6)	76	(8.0)	36	(7.9)	90	(11.5)
		Winter	88	117[a]	(9.3)	79[a]	(7.5)	38[a]	(8.0)	87	(9.2)
	Beer Sheva	Summer	42	109	(7.3)	74	(7.1)	35	(6.3)	84	(11.0)
		Winter	29	116[a]	(9.9)	78[a]	(6.4)	38	(7.0)	90[a]	(13.5)

(TABLE 7A continued)

Work	Sdom	Summer	66	122	(10.6)	81	(9.5)	41	(12.3)	103	(17.3)
		Winter	98	123	(11.2)	79	(9.9)	44	(10.6)	101	(19.3)
	Beer Sheva	Summer	34	114	(7.6)	74	(7.9)	40	(8.8)	98	(10.8)
		Winter	38	125[a]	(11.0)	80[a]	(11.6)	45[a]	(10.8)	102	(13.9)

X Mean

S.D. Standard deviation

a Statistically significant (P≤0.05) differences between summer and winter.

TABLE 7B. Blood pressure, pulse pressure and heart rate recorded during the work shift: Sdom and Beer Sheva.

Condition	Season	Plant	Number of measurements	Blood Pressure (mm Hg) Systolic $\bar{X}$	Systolic S.D.	Diastolic $\bar{X}$	Diastolic S.D.	Pulse Pressure (mm Hg) $\bar{X}$	Pulse Pressure S.D.	Heart Rate (beats/min) $\bar{X}$	Heart Rate S.D.
Rest in air conditioned clinic, before work shift	Summer	Sdom	36	118	(8.9)	80	(7.4)	38	(7.2)	81	(12.5)
		Beer Sheva	13	106[b]	(7.7)	75[b]	(5.6)	31[b]	(7.3)	79	(10.5)
	Winter	Sdom	31	119	(9.7)	82	(8.4)	37	(8.6)	83	(10.4)
		Beer Sheva	16	122	(10.2)	83	(7.4)	39	(5.7)	82	(14.0)
Rest in air conditioned clinic after work shift	Summer	Sdom	36	116	(7.2)	79	(6.9)	37	(7.4)	86	(10.7)
		Beer Sheva	13	108[b]	(7.2)	74[b]	(7.3)	34[b]	(7.1)	79[b]	(10.5)
	Winter	Sdom	31	118	(9.2)	81	(6.9)	37	(6.8)	89	(9.9)
		Beer Sheva	16	117	(9.4)	80	(6.7)	37	(6.2)	88	(9.7)
Rest in work area during work shift	Summer	Sdom	188	112	(8.6)	75	(8.9)	37	(8.7)	89	(11.3)
		Beer Sheva	56	108[b]	(7.4)	74	(6.6)	34[b]	(7.1)	83[b]	(10.9)
	Winter	Sdom	109	117	(9.1)	79	([illegible].0)	38	(8.0)	88	(9.1)
		Beer Sheva	53	118	(8.8)	78	(7.0)	40	(7.3)	89	(12.9)

(TABLE 7B continued)

Work	Summer	Sdom	101	122[b]	(13.0)	81[b]	(10.0)	41	(12.2)	100	(15.5)
		Beer Sheva	51	114	(7.4)	74	(7.3)	40	(8.1)	97	(10.4)
	Winter	Sdom	118	123	(11.8)	78	(11.4)	45	(10.5)	101	(18.3)
		Beer Sheva	66	125	(10.4)	80	(10.5)	45	(10.1)	101	(12.7)

X Mean

S.D. Standard deviation

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva.

TABLE 8A. Blood pressure, pulse pressure and heart rate recorded during the two parts of the work shift: Summer and Winter.

Work shift	Conditions	Plant	Season	Number of measure-ments	Blood Pressure (mm Hg) Systolic		Diastolic		Pulse Pressure (mm Hg)		Heart Rate (beats/min)	
					X	S.D.	X	S.D.	X	S.D.	X	S.D.
1st part of work shift	Rest (In work area)	Sdom	Summer	86	112[a]	(7.7)	76[a]	(8.0)	36	(8.4)	89	(11.6)
			Winter	57	117	(9.7)	80	(7.7)	37	(8.2)	87	(9.5)
		Beer Sheva	Summer	26	108[a]	(7.5)	73[a]	(7.2)	35	(7.6)	83	(10.3)
			Winter	15	116	(11.1)	78	(6.9)	38	(7.5)	90	(15.0)
	Work	Sdom	Summer	46	121	(9.9)	83	(9.1)	38[a]	(9.7)	100	(14.5)
			Winter	71	124	(11.2)	80	(9.4)	44	(11.0)	99	(20.3)
		Beer Sheva	Summer	24	114[a]	(8.5)	75[a]	(8.3)	39	(9.2)	96	(10.8)
			Winter	24	125	(11.8)	84	(10.8)	41	(10.1)	103	(14.6)

(TABLE 8A continued)

2nd part of work shift	Rest (In work area)	Sdom	Summer	44	111[a]	(7.6)	74[a]	(7.8)	37	(7.1)	91	(11.2)
			Winter	31	117	(8.7)	78	(7.0)	39	(7.4)	89	(8.5)
		Beer Sheva	Summer	15	110	(7.2)	75	(7.0)	35	(3.7)	85	(12.3)
			Winter	14	115	(8.8)	78	(6.1)	37	(6.6)	91	(12.1)
	Work	Sdom	Summer	20	125	(11.9)	78	(9.5)	47	(15.1)	110	(21.7)
			Winter	27	120	(11.3)	76	(10.8)	44	(9.5)	106	(15.5)
		Beer Sheva	Summer	10	116[a]	(5.0)	74	(7.4)	42[a]	(8.2)	101	(10.4)
			Winter	14	124	(9.7)	74	(10.6)	50	(10.2)	100	(12.6)

X Mean

S.D. Standard deviation

a Statistically significant ($P \leq 0.05$) differences between summer and winter.

TABLE 8B. Blood pressure, pulse pressure and heart rate recorded during the two parts of the work shift: Sdom and Beer Sheva.

Work shift	Conditions	Season	Plant	Number of measurements	Blood Pressure (mm Hg) Systolic $\bar{X}$	Systolic S.D.	Diastolic $\bar{X}$	Diastolic S.D.	Pulse Pressure (mm Hg) $\bar{X}$	Pulse Pressure S.D.	Heart Rate (beats/min) $\bar{X}$	Heart Rate S.D.
1st part of work shift	Rest (in work area)	Summer	Sdom	127	112 b	(8.4)	76	(8.0)	36	(9.0)	89 b	(11.4)
			Beer Sheva	36	108	(7.4)	74	(6.7)	34	(7.6)	82	(10.4)
		Winter	Sdom	71	116	(9.6)	79	(8.0)	37	(8.3)	88	(9.4)
			Beer Sheva	29	117	(8.7)	77	(7.7)	40	(7.6)	88	(13.5)
	Work	Summer	Sdom	73	121 b	(10.9)	82 b	(9.2)	39	(10.2)	98	(12.8)
			Beer Sheva	33	114	(7.6)	75	(7.9)	39	(8.4)	96	(10.5)
		Winter	Sdom	84	124	(11.6)	79	(11.0)	45	(10.7)	99	(19.3)
			Beer Sheva	44	126	(11.4)	81	(10.5)	45	(10.1)	102	(13.0)

(TABLE 8B continued)

2nd part of work shift	Rest (In work area)	Summer	Sdom	61	110	(8.8)	73	(8.4)	37	(7.9)	90	(11.0)
			Beer Sheva	20	109	(7.5)	74	(6.5)	35	(6.1)	84	(11.5)
		Winter	Sdom	38	117	(8.1)	78	(8.1)	39	(7.5)	90	(8.4)
			Beer Sheva	24	117	(9.1)	78	(6.0)	39	(7.2)	91	(12.1)
	Work	Summer	Sdom	28	126 b	(16.9)	78	(12.1)	48 b	(14.5)	107	(19.8)
			Beer Sheva	18	115	(7.2)	74	(6.3)	41	(7.5)	101	(9.8)
		Winter	Sdom	34	121	(12.4)	76	(12.0)	45	(10.1)	107	(14.7)
			Beer Sheva	22	124	(8.4)	76	(9.8)	48	(9.8)	98	(12.1)

X Mean

S.D. Standard deviation

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva.

TABLE 9. Blood Pressure and Heart Rate comparisons between the conditions during the work shift.

Plant	Season	Condition	Blood pressure (mm Hg) Systolic	Diastolic	Pulse Pressure (mm Hg)	Heart rate (beats/min)	
a) Sdom	Summer	Rest	*+112** (9)	+75(8)	+37(9)	+89(11)	Comparison between rest during work shift (in work area) and work during the work shift.
		Work	+122 (13)	+81(10)	+41(12)	+100(16)	
	Winter	Rest	+117 (9)	79(8)	+38(8)	+88(9)	
		Work	+123 (12)	78(11)	+45(11)	+101(16)	
Beer Sheva	Summer	Rest	+108 (7)	74(7)	+34(7)	+83(11)	
		Work	+114 (7)	74(7)	+40(8)	+97(10)	
	Winter	Rest	+118 (9)	78(7)	+40(7)	+89(13)	
		Work	+125 (10)	80(11)	+45(10)	+101(13)	
b) Sdom	Summer	Rest (Before)	118 (9)	80(7)	38(7)	81(13)	Comparison between rest in clinic after work shift.
		Rest (After)	116 (7)	79(7)	37(7)	86(11)	
	Winter	Rest (Before)	119 (10)	82(8)	37(9)	+83(10)	
		Rest (After)	118 (9)	81(7)	37(7)	+89(10)	
Beer Sheva	Summer	Rest (Before)	106 (8)	75(6)	31(7)	79(11)	
		Rest (After)	108 (7)	74(7)	34(7)	79(11)	
	Winter	Rest (Before)	122 (10)	83(7)	39(6)	82(14)	
		Rest (After)	117 (9)	80(7)	37(6)	88(10)	

+ Statistically significant ($P \leq 0.05$) differences between the conditions.

* Mean

** Standard deviation.

TABLE 10. Blood Pressure and Heart Rate comparisons between rest and work during the two parts of the work shift.

Work shift	Plant	Season	Condition	Blood Pressure (mm Hg) Systolic	Blood Pressure (mm Hg) Diastolic	Pulse Pressure (mm Hg)	Heart rate (beats/min)
1st part of work shift	Sdom	Summer	Rest	+112* (8)**	+76(8)	36(9)	+89(11)
			Work	+121 (11)	+82(9)	39(10)	+98(13)
		Winter	Rest	+116 (10)	79(8)	+37(8)	+88(9)
			Work	+124 (12)	79(11)	+45(11)	+99(19)
	Beer Sheva	Summer	Rest	+108 (7)	74(7)	+34(8)	+82(11)
			Work	+114 (8)	75(8)	+39(8)	+96(11)
		Winter	Rest	+117 (9)	77(8)	+40(8)	+88(14)
			Work	+126 (11)	81(11)	+45(10)	+102(13)
2nd part of work shift	Sdom	Summer	Rest	+110 (9)	+73(8)	+37(8)	+90(11)
			Work	+126 (17)	+78(12)	+48(15)	+107(20)
		Winter	Rest	117 (8)	78(8)	+39(8)	+90(8)
			Work	121 (12)	75(12)	+45(10)	+107(15)
	Beer Sheva	Summer	Rest	+109 (8)	74(7)	+35(6)	+84(18)
			Work	+115 (7)	74(6)	+41(8)	+101(10)
		Winter	Rest	+117 (9)	78(6)	+39(7)	+91(12)
			Work	+124 (8)	76(10)	+48(10)	+98(12)

+ Statistically significant ($P \leq 0.05$) differences between the conditions.

* Mean

** Standard deviation.

5 Body weights:

The weights in both plants and in both seasons were similar (Table 6A). In Sdom in both seasons and in Beer Sheva in winter there were no weight losses during the work shifts. In Beer Sheva in summer there was an average weight loss of 0.4 Kg (Table 6B).

C. Internal environment studies:

1. Blood and urine chemistry:

a) Blood: Most of the constituents which were determined in the blood and sera were within the normal range of the Soroka Medical Center (Tables 11A, B). The total protein concentrations were above the normal range. The hemoglobin and creatinine concentrations were on the upper border of the normal range. The differences during the work shifts in the constituents determined in the blood and sera were slight if at all in both plants in both seasons. The same was observed concerning the differences between the seasons, as well as the differences between the plants (Tables 11A, B).

In both plants the total protein serum concentrations were significantly higher in summer than they were in winter (Table 11B).

In Sdom, in both seasons (and especially in summer), the serum potassium concentrations were high (Table 11A). In both seasons there was a decrease in the serum potassium concentrations at the end of the work shifts (Table 11A). This decrease was greater in summer than in winter.

The potassium serum concentrations in Sdom before the work shifts in summer were significantly higher than in winter. The opposite was observed in Beer Sheva (Table 11B). In Beer Sheva, the serum potassium concentrations were slightly lower than in Sdom (Table 11A).

TABLE 11A. Blood variables measured before and after the work shifts: Sdom and Beer Sheva.

Season			Summer				Winter			
Plant			Sdom		Beer Sheva		Sdom		Beer Sheva	
Time			Before	After	Before	After	Before	After	Before	After
n			32	32	9	9	28	28	9	9
Variable	Units	Normal Range								
BUN (Blood urea Nitrogen)	mg %	≤ 25	18.3	19.3	16.5	18.2	17.1	17.5	17.9	19.7
			(3.8)	(3.9)	(3.7)	(3.6)	(4.0)	(3.9)	(3.8)	(3.3)
Creatinine	mg %	≤ 1.1	0.9	1.1	1.1	1.3	0.9	1.0	0.9	1.0
			(0.1)	(0.2)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)
Uric Acid	mg %	3.0-7.0	5.9	6.0	5.2	5.4	5.8	6.0	5.8	6.0
			(1.1)	(1.0)	(0.9)	(0.8)	(1.0)	(1.1)	(0.9)	(0.8)
Na	mEq/l	135-142	140	141	139	140	138	138	138	138
			(3.0)	(2.6)	(1.8)	(1.8)	(2.1)	(1.9)	(1.2)	(1.1)
K	mEq/l	3.5-5.0	5.3^{ab}	4.3^{ab}	3.5^{b}	3.6^{b}	4.9^{ab}	4.4^{a}	4.4^{b}	4.3
			(0.6)	(0.4)	(0.3)	(0.3)	(0.5)	(0.4)	(0.4)	(0.3)
Total protein	gm %	6.0-7.5	8.3	8.4	8.0	8.2	7.5	7.5	7.1	7.3
			(0.7)	(0.8)	(0.4)	(0.6)	(0.5)	(0.3)	(0.4)	(0.5)
Albumin	gm %	3.8-4.7	4.0	4.0	3.9	3.9	4.1	4.0	4.0	4.0
			(0.3)	(0.3)	(0.1)	(0.1)	(0.2)	(0.4)	(0.2)	(0.2)
Globulin	gm %	2.2-2.8	4.2	4.4	4.2	4.3	3.4	3.5	3.1	3.4
			(0.7)	(0.8)	(0.4)	(0.6)	(0.5)	(0.4)	(0.4)	(0.5)
Hgb	gm	14-18	17.3	16.5	17.7	17.3	17.0	16.6	17.1	16.4
			(1.2)	(1.1)	(1.0)	(1.2)	(1.2)	(1.4)	(1.4)	(1.0)
Hct	%	42-52	46.9^{a}	44.6^{a}	47.8^{a}	45.7^{a}	47.7^{ab}	45.5^{a}	50.3^{ab}	46.6^{a}
			(2.5)	(2.5)	(3.0)	(3.2)	(2.5)	(2.9)	(3.9)	(4.3)
Osmolality	mOsm/Kg	280-300	288^{b}	288^{b}	282^{b}	282^{b}	289^{b}	289^{b}	285^{b}	285^{b}
			(8.7)	(6.6)	(4.3)	(3.5)	(5.5)	(4.2)	(7.0)	(4.9)

a Statistically significant ($P \leq 0.05$) differences between before and after work shift.
b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva.
* Mean. ** Standard deviation.

TABLE 11B. Blood variables measured before and after the work shifts: Summer and Winter.

Plant		Sdom				Beer Sheva			
Season		Summer		Winter		Summer		Winter	
Time		Before	After	Before	After	Before	After	Before	After
n		20	20	20	20	9	9	9	9
Variables	Units								
BUN (Blood urea Nitrogen)	mg %	*18.4	19.8	16.9	17.4	18.0	19.3	17.7	19.1
		**(4.0)	(4.3)	(3.9)	(3.8)	(3.4)	(3.7)	(4.5)	(3.7)
Creatinine	mg %	0.9	1.1	0.9	1.0	1.1	1.3	0.9	1.0
		(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)
Uric Acid	mg %	5.8	6.0	5.5	5.8	5.0	5.2	5.6	5.6
		(1.1)	(1.0)	(1.1)	(1.1)	(1.0)	(0.8)	(0.8)	(0.6)
Na	mEq/l	140	141	138	138	138	140	138	138
		(3.3)	(2.5)	(1.9)	(2.0)	(1.5)	(1.8)	(1.0)	(1.5)
K	mEq/l	5.3^{c}	4.4	4.9^{c}	4.4	3.5^{c}	3.6^{c}	4.4^{c}	4.2^{c}
		(0.7)	(0.4)	(0.5)	(0.4)	(0.2)	(0.3)	(0.5)	(0.3)
Total Protein	gm %	8.3^{c}	8.5^{c}	7.5^{c}	7.6^{c}	8.0^{c}	8.3^{c}	6.9^{c}	7.2^{c}
		(0.9)	(0.9)	(0.5)	(0.3)	(0.4)	(0.6)	(0.4)	(0.6)
Albumin	gm %	4.0	4.0	4.1	4.1	3.8	3.9	3.9	3.8
		(0.2)	(0.2)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(0.2)
Globulin	gm %	4.4^{c}	4.5^{c}	3.4^{c}	3.5^{c}	4.2^{c}	4.4^{c}	3.0^{c}	3.4^{c}
		(0.8)	(0.9)	(0.5)	(0.4)	(0.4)	(0.6)	(0.4)	(0.5)
Hgb	gm	17.0	16.2	17.0	16.8	17.5	16.9	17.1	16.2
		(1.2)	(1.1)	(1.3)	(1.5)	(1.0)	(1.2)	(1.4)	(0.7)

(TABLE 11B continued)

Hct	%	46.6	44.3	48.1	45.8	47.1	45.0	49.0	44.9
		(2.7)	(2.6)	(2.7)	(2.8)	(2.5)	(3.2)	(2.0)	(3.2)
Osmo-lality	mOsm/Kg	289	288	289	289	282	282	285	286
		(8.8)	(6.9)	(5.3)	(4.3)	(4.3)	(3.5)	(7.2)	(5.2)

c Statistically significant ($P \leq 0.05$) differences between summer and winter

* Mean

** Standard deviation.

b) Urine: Qualitative tests for glucose, protein and blood in urine performed on the urine samples were within the normal range.

The urine osmolality before and after the work shifts were about 900 mOsm/Kg. No significant differences were found between the samples before and after the work shifts in summer or in winter in either plant (Table 12A). Further, no significant differences were found either between the different seasons or between the two plants (Tables 12A, B).

TABLE 12A. Urine variables measured before and after the work shifts: Sdom and Beer Sheva.

		Summer				Winter			
Plant		Sdom		Beer Sheva		Sdom		Beer Sheva	
Time		Before	After	Before	After	Before	After	Before	After
n		36	36	13	13	33	33	17	17
Variables	Units								
Creatinine	mg %	*218[b]	225	161[b]	177	174	162	181	157
		**(86.7)	(68.3)	(60.8)	(62.5)	(78.2)	(76.5)	(103.5)	(56.6)
pH	pH units	5.4	5.4	5.4	5.5	5.7	5.9	5.4	5.6
		(0.5)	(0.3)	(0.3)	(0.4)	(0.5)	(0.6)	(0.6)	(0.6)
Osmolality	mOsm/Kg	929	998	912	1000	892	937	869	897
		(142.1)	(99.7)	(175.7)	(164.2)	(184.8)	(121.3)	(230.0)	(195.8)

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva

* Mean

** Standard deviation.

TABLE 12B. Urine variables measured before and after the work shifts: Summer and Winter.

Plant		Sdom				Beer Sheva			
Season		Summer		Winter		Summer		Winter	
Time		Before	After	Before	After	Before	After	Before	After
n		25	25	25	25	9	9	9	9
Variables	Units								
Creatinine	mg %	*197	228	175	161	180	192	176	169
		**(77.9)	(68.7)	(86.1)	(81.1)	(60.6)	(64.8)	(101.1)	(67.3)
pH	pH Units	5.4	5.4	5.6	5.8	5.4	5.3	5.4	5.6
		(0.6)	(0.4)	(0.4)	(0.5)	(0.3)	(0.3)	(0.6)	(0.5)
Osmolality	mOsm/Kg	929	998	892	937	912	1000	869	897
		(142.1)	(99.7)	(184.8)	(121.3)	(175.7)	(164.2)	(230.0)	(195.8)

* Mean

** Standard deviation

2. Hormonal levels:

The serum levels of aldosterone, cortisol, thyroxine, and triiodothyronine in both plants and in both seasons were within the normal range (Tables 13A, B).

a) Aldosterone: The aldosterone levels in Beer Sheva in winter were significantly lower at the end of the work shifts than before (Table 13A). The levels in Sdom were higher in summer than in winter (Table 13B). In winter the levels were lower in Sdom than in Beer Sheva (Table 13A).

b) Cortisol: In both plants there was a significant decrease in the serum cortisol levels at the end of the work shifts than before (Table 13A). In Sdom the cortisol levels were significantly lower in summer than in winter (Table 13B).

c) Thyroxine (T-4) and triiodothyronine (T-3): In both plants the T-4 levels were significantly higher in summer than they were in winter, while the opposite was observed regarding the T-3 levels (Table 13B). The T-4 was about 20% higher, while the T-3 was about 10% lower in summer than in winter.

In both plants the T-3/T-4 ratio was about 25% lower in summer than in winter (Table 14B).

TABLE 13A. Hormonal evolutions before and after the work shifts: Sdom and Beer Sheva.

Season			Summer				Winter			
Plant			Sdom		Beer Sheva		Sdom		Beer Sheva	
Time			Before	After	Before	After	Before	After	Before	After
Hormone	Units	Normal Range								
Cortisol	ng/ml	50-200	a*90.7	a55.3	a104.2	a45.2	a103.6	a58.4	a122.8	a60.2
			**(32.1)	(24.8)	(40.3)	(21.1)	(30.1)	(19.1)	(40.4)	(29.0)
			***(29)	(29)	(11)	(11)	(28)	(28)	(17)	(17)
Aldos-terone	Pg/ml	12-125	99.1	85.8	111.3	89.1	b67.8	71.5	ab109.3	a64.0
			(33.6)	(36.1)	(42.6)	(33.1)	(33.3)	(39.6)	(53.1)	(44.2)
			(22)	(22)	(9)	(9)	(20)	(20)	(12)	(12)
Thyroxine (T-4)	mcg/ 100ml	4.7-10.7	7.9	7.7	7.6	7.4	6.4	6.6	a6.4	a6.1
			(1.8)	(1.4)	(0.7)	(0.9)	(1.5)	(1.4)	(1.1)	(0.9)
			(30)	(30)	(11)	(11)	(25)	(25)	(17)	(17)
Trii-dothyro-nine (T-3)	ng/ 100ml	75-220	ab200.9	a183.4	b182.3	179.3	a217.8	a205.1	a209.4	a200.1
			(24.5)	(25.6)	(14.5)	(22.6)	(40.3)	(27.7)	(17.1)	(20.8)
			(30)	(30)	(12)	(12)	(28)	(28)	(17)	(17)

a Statistically significant ($P \leq 0.05$) differences between before and after the work shifts.

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva.

* Mean

** Standard deviation

*** Number of workers.

TABLE 13B. Hormonal evaluations before and after the work shifts: Summer and Winter.

Plant		Sdom				Beer Sheva			
Season		Summer		Winter		Summer		Winter	
Time		Before	After	Before	After	Before	After	Before	After
Hormone	Units								
Cortisol	ng/ml	*^{c}79.0	^{c}46.8	^{c}100.4	^{c}58.3	116.9	45.4	142.8	61.5
		**(23.5)	(14.7)	(34.5)	(19.9)	(34.6)	(20.5)	(39.6)	(26.4)
		***(18)	(19)	(18)	(19)	(8)	(8)	(8)	(8)
Aldos-terone	Pg/ml	^{c}95.2	80.7	^{c}59.9	61.4	113.4	98.5	115.2	72.5
		(29.6)	(33.5)	(33.0)	(31.7)	(46.0)	(37.3)	(57.4)	(38.0)
		(13)	(15)	(13)	(15)	(7)	(7)	(7)	(7)
Thyroxine (T-4)	mcg/100ml	^{c}7.7	^{c}7.4	^{c}6.4	^{c}6.6	^{c}7.3	^{c}7.3	^{c}6.3	^{c}5.9
		1.7	(1.3)	(1.7)	(1.6)	(0.8)	(1.0)	(1.2)	(0.9)
		(17)	(17)	(17)	(17)	(7)	(8)	(7)	(8)
Triiodothyronine (T-3)	ng/100ml	^{c}195.7	^{c}176.6	^{c}212.0	^{c}200.9	^{c}176.0	^{c}171.7	^{c}203.9	^{c}197.3
		(21.0)	(23.7)	(24.2)	(27.0)	(11.7)	(20.3)	(16.7)	(19.8)
		(19)	(19)	(19)	(19)	(8)	(8)	(8)	(8)

c Statistically significant ($P \leq 0.05$) differences between summer and winter.

* Mean

** Standard deviation

*** Number of workers.

TABLE 14A. Triiodothyronine (T-3) to thyroxine (T-4) ratios before and after the work shifts: Sdom and Beer Sheva.

Season	Summer				Winter			
Plant	Sdom		Beer Sheva		Sdom		Beer Sheva	
Time	Before	After	Before	After	Before	After	Before	After
n	30	30	11	12	25	25	17	17
	*0.027	0.025	0.025	0.025	0.037	0.032	0.033	0.034
	**(0.007)	(0.005)	(0.002)	(0.004)	(0.018)	(0.009)	(0.006)	(0.006)

* Mean

** Standard deviation

TABLE 14B. Triiodothyronine (T-3) to thyroxine (T-4) ratios before and after the work shifts: Summer and Winter.

Plant	Sdom				Beer Sheva			
Season	Summer		Winter		Summer		Winter	
Time	Before	After	Before	After	Before	After	Before	After
n	17	17	17	17	7	7	7	7
	*c0.027	c0.025	c0.037	c0.032	c0.025	c0.024	c0.034	c0.034
	**(0.007)	(0.006)	(0.070)	(0.010)	(0.003)	(0.005)	(0.006)	(0.005)

* Mean

** Standard deviation

c Statistically significant ($P \leq 0.05$) differences between summer and winter.

II. Survey of cardiovascular and urogenitial disorders:

A. Certificates of illness:

The certificates of illness of all the employees (769) of the plant, from Jan. 1, 1971 to Dec. 31, 1976 were collected. 47 employees were found to be suffering from diseases of the cardiovascular system (functional heart diseases, acute inflammatory heart diseases, arterioscleratic and degenerative heart diseases); 7 from coronary diseases; 33 from hypertensive diseases; and 60 from diseases of the urogenitial system, in Sdom.

About 70% of all the employees in Sdom were exposed to heat during their work shifts while 30% were not. Among those workers wo were suffering from dis-orders of the cardiovascular and urogenitial systems, about 70% were heat exposed workers, while the remaining 30% were not (Table 15).

Within the subgroups of workers who suffered from cardiovascular and urogenitial disorders and were younger than 46 there were proportionately more unexposed workers (Table 16). The same was observed concerning those who worked less than 11 years (Table 17).

The proportion of the heat exposed workers within the subgroup who suffered from cardiovascular and urogenitial disorders and were older than 46 was greater (Table 16). The same was observed concerning the seniority group greater than 11 years (Table 17).

TABLE 15. The proportion of the heat exposed and unexposed workers within the subgroup suffering from cardiovascular and urogenitial disorders in Sdom*.

	Heat Exposed	Unexposed
Number of employees	536	233
% of all the employees	69.7	30.3
% of the subgroup of employees who suffered from:		
Cardiovascular system diseases**	66.0	34.0
Coronary diseases	57.1	42.9
Hypertensive diseases	69.7	30.3
Urogenitial system diseases	71.7	28.3

* Data derived from the certificates of illness.

** Including functional heart diseases, arterioscleratic and degenerative heart diseases.

TABLE 16. The proportion of the heat exposed and unexposed workers within the subgroup suffering from cardiovascular and urogenitial disorders with regard to age in Sdom[1].

Age (yrs.)	≤ 45			≥ 46		
	HE[2]	UE[3]		HE	UE	
Number of employees	423	269		113	64	
% of all the employees	55.0	22.0		14.7	8.3	
% of the subgroup of employees who suffered from:						
Cardiovascular system diseases[4]	27.7	19.1	(47.8)*	38.3	14.9	(26.4)*
Coronary diseases	0	0	(0)	57.1	42.9	(76.0)
Hypertensive diseases	24.2	15.2	(38.0)	45.5	15.2	(26.9)
Urogenitial system diseases	43.3	18.3	(45.8)	28.3	10.0	(17.7)

1 Data derived from the certificates of illness.

2 Heat exposed workers.

3 Unexposed workers.

4 Including functional heart diseases, arterioscleratic and degenerative heart diseases.

* Adjusted (see methods).

TABLE 17. The proportion of the heat exposed and unexposed workers within the subgroups suffering from cardiovascular and urogenitial disorders with regard to seniority in Sdom[1].

Seniority (yrs.)	≤10			≥11		
	HE[2]	UE[3]		HE	UE	
Number of employees	285	106		251	127	
% of all the employees	37.1	13.8		32.6	16.5	
% of the subgroup of employees who suffered from:						
Cardiovascular system diseases[4]	6.8	9.1	(25.5)*	63.6	22.7	(44.8)*
Coronary diseases	0	0	(0)	57.1	42.9	(84.8)
Hypertensive diseases	6.3	9.4	(25.3)	65.6	18.8	(37.1)
Urogenitial system diseases	10.0	11.7	(31.5)	61.7	16.7	(33.0)

1 Data derived from the certificates of illness.

2 Heat exposed workers

3 Unexposed workers

4 Including functional Heart diseases, arterioscleratic and degenerative heart diseases.

* Adjusted (see methods).

B. Electrocardiogram (ECG) and blood pressure examinations:

Half the workers of the plant (398) underwent ECG and blood pressure examinations during the work shifts in summer after at least 15 min rest in the air-conditioned plant clinic. The ECG of 30 workers were found to be abnormal and the blood pressure of 34 were found to be abnormally high in Sdom and in their place of residence. Within the subgroup of workers who were diagnosed as having an abnormal ECG and hypertension, there were proportionately more heat exposed workers (Table 18). This was also found regarding age and seniority (Tables 19, 20).

Besides the above mentioned group of workers who were consistently found to have abnormally high blood pressures (both at work and at home) there were 24 other workers, most of whom were heat exposed, whose abnormally high blood pressures were recorded only in the plant clinic in Sdom in summer. Repetitive measurements taken in summer at their place of residence (Arad, Beer Sheva or Dimona) by their family physician showed that their blood pressures were normal. The major difference was that the diastolic pressure was about 18 mmHg higher in Sdom than at their place of residence (Table 21). In winter, two and a half years later 14 of these workers underwent additional blood pressure measurements in Sdom. The blood pressures of 10 of these workers were lower than they were in summer. The major difference was that the diastolic pressure was about 15 mmHg lower than in summer (Table 22).

The blood pressure of these workers in Sdom in winter was similar to those measured at their place of residence (Table 23). The blood pressure of the other 4 (all of who were heat exposed) taken in Sdom was the same in both summer and winter. One of the four workers has since been diagnosed as hypertensive and is undergoing treatment.

TABLE 18. The proportion of the heat exposed and unexposed workers within the subgroup with abnormal ECG and hypertension in Sdom*.

	Heat exposed	Unexposed
Number of employees examined	267	131
% of all the employees examined	67.1	32.9
% of the subgroup of employees diagnosed with:		
Abnormal ECG	83.3	16.7
Hypertension	79.4	20.6

* Data derived from ECG and blood pressure examinations.

TABLE 19. The proportion of the heat exposed and unexposed workers within the subgroup with abnormal ECG and hypertension with regards to age in Sdom[1].

Age (yrs.)	≤45			≥46		
	HE[2]	UE[3]		HE	UE	
Number of employees examined	204	97		63	34	
% of all the employees examined	51.3	24.4		15.8	8.5	
% of the subgroup of employees diagnosed with:						
Abnormal ECG	30.0	3.3	(6.9)*	53.3	13.3	(24.7)
Hypertension	32.4	8.8	(18.5)	47.1	11.8	(21.9)

1 Data derived from ECG and blood pressure examinations.

2 Heat exposed workers

3 Unexposed workers

* Adjusted (see methods).

TABLE 20. The proportion of the heat exposed and unexposed workers within the subgroup with abnormal ECG and hypertension with regard to seniority in Sdom[1].

Seniority (yrs.)	≤10			≥11		
	HE[2]	UE[3]		HE	UE	
Number of employees examined	116	63		151	68	
% of all the employees examined	29.2	15.8		37.9	17.1	
% of the subgroup of employees diagnosed with:						
Abnormal ECG	20.0	3.3	(6.1)*	63.3	13.3	(29.5)
Hypertension	23.5	2.9	(5.4)	55.9	17.6	(39.0)

1 Data derived from ECG and blood pressure examinations.

2 Heat exposed workers.

3 Unexposed workers.

* Adjusted (see methods).

TABLE 21. Blood pressure measurements of the transitional group* in summer at Sdom and at their place of residence.

	Blood pressure (mm Hg)			
	Systolic		Diastolic	
Sdom	142[a]	(10)[b]	103	(5)
Place of residence	137	(14)	85	(6)

* 24 workers whose blood pressures were abnormally high only in summer at Sdom.

a Mean

b Standard deviation.

TABLE 22. Blood pressure measurements of 10 workers of the transitional group whose blood pressures differed in summer than winter at Sdom.

	Blood pressure (mm Hg)			
	Systolic		Diastolic	
Summer	144[a]	(10)[b]	103	(5)
Winter	136	(9)	89	(2)

a Mean

b Standard deviation.

TABLE 23. Blood pressure measurements of 10 workers of the transitional group* in summer at their place of residence and in winter at Sdom.

	Blood pressure (mm Hg)			
	Systolic		Diastolic	
Place of residence (summer)	139[a]	(16)[b]	85	(5)
Sdom (winter)	136	(9)	89	(2)

* The blood pressure of these workers differed in summer than winter in Sdom.

a Mean.

b Standard deviation.

C. <u>Comparison of Sdom and Beer Sheva</u>:

The frequencies of cardiovascular and urogenitial disorders in general were higher in Beer Sheva than in Sdom (Tables 24, 25).

The distribution of the employees of the two plants by age and seniority are presented in Fig. 7. The age of most of the workers in Sdom was between 25 and 45, while in Beer Sheva it was between 41 and 50. In Sdom the majority of the employees worked up to 15 years, whereas in Beer Sheva the majority worked more than 10 years.

TABLE 24. The frequencies of cardiovascular and urogenitial disorders in Sdom and Beer Sheva*.

	Sdom	Beer Sheva
Number of employees	769	114
% of the employees who suffered from:		
Cardiovascular system diseases**	6.1	16.7
Coronary diseases	0.8	8.8
Hypertensive diseases	4.3	16.7
Urogenitial system diseases	8.0	21.9

* Data from the certificates of illness.

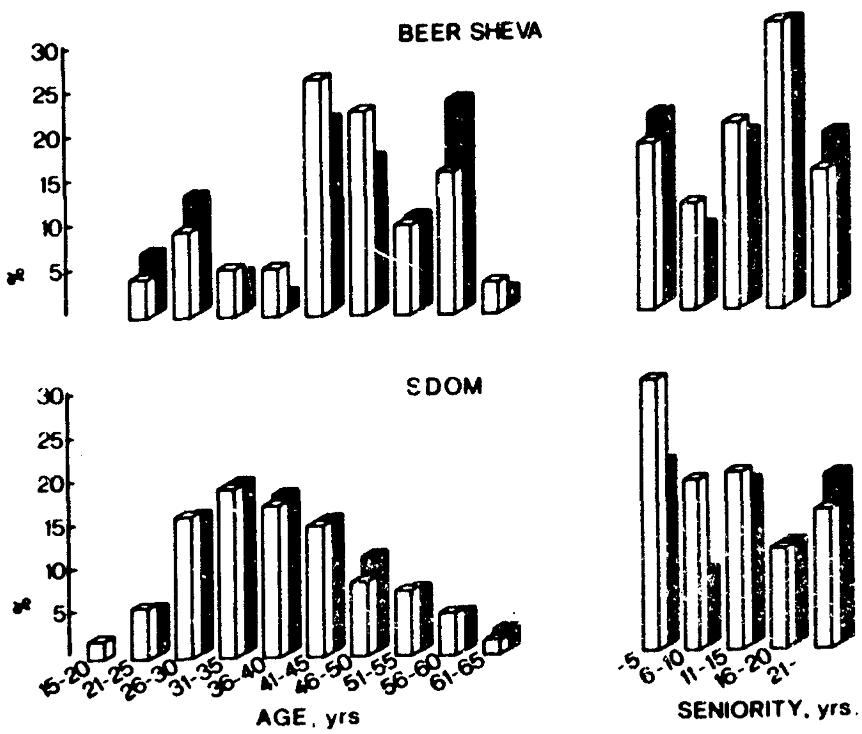
** Including functional heart diseases, arterioscleratic and degenerative heart diseases.

TABLE 25. The frequencies of abnormal ECG and hypertension in Sdom and Beer Sheva*.

	Sdom	Beer Sheva
Number of employees examined	398	47
% of the employees examined diagnosed with:		
Abnormal ECG	7.5	4.3
Hypertension	8.5	19.1

* Data derived from the ECG and blood pressure examinations.

Fig. 7. The distribution of all the employees of the plants and of those who underwent ECG and blood pressure examinations according to age and seniority.



Empty bars (in front) are of all the workers of the plant. Expressed as a per cent of all the workers of the plant. Full bars (in back) are of the workers who were examined. Expressed as a per cent of all the workers examined.

DISCUSSION

The physiological reactions of the workers during their normal eight hours work shift must be considered in relation to "stress" and "strain". A clear distinction must therefore be made between these terms. Stress is best considered as an attribute of the environment whereas strain is an attribute of the individual. Therefore, the term stress as used in the following discussion, refers to the change, physiological or otherwise, induced in the individual by exposure to the stressful environment.

With this distinction in mind, elaboration on the specific techniques for assessing stress and strain in the present study is presently in order.

I. Studies of a normal work shift:

A. Heat stress evaluation:

There are four measurable factors which determine the level of heat stress imposed by the environment - air temperature, radiant heat exchange, air movement and humidity. These can interact with one another so that the effect of any one factor may be determined by the level of another. For example, an increase in air movement (wind speed) will exert a cooling effect and diminish the heat stress if the air temperature is below that of the skin. If the air temperature is above skin temperature it can increase the heat stress by increasing the convective heat gain of the body. The exact effect of air movement will be determined by, among other things, the prevailing level of humidity. The combined effect of the four factors just mentioned is further uniquely determined in each case by the rate of energy expenditure and the clothing worn by the person exposed to them.

For many years, scientists have been searching for a single index of heat stress which will embody the combined effect of two or more of the four component factors. In some indices all four of the above mentioned component factors, as well as the level of energy expenditure and the clothing of the individual concerned have been included. The different indices are usually determined with the aid of physical measurements of ordinary air temperature (dry bulb), radiant temperature, relative humidity (wet bulb) and air velocity (26).

There are fundamental differences between the heat stress indices, as Kerslake (55) pointed out in his comparative discussion on the subject. Some of these are based on physiological observations (e.g. Predicted 4-Hour Sweat Rate), others on subjective preference (Effective Temperature) or on analytical arguments on heat exchange (Belding and Hatch Heat Stress Index). Whereas some indices can be calculated from nomograms, others require the combination of several nomograms.

As the previous paragraph indicates, the effort to evolve a single heat stress index has been seriously complicated by a variety of factors. Expanding upon this point, a review prepared by Belding (7) lists numerous systems for rating heat stress. In this review, he points out that many of these systems have obvious limitations which prevent them from ever gaining widespread usage. Others, which became popular for a time, have since lost their popularity because shortcomings were discovered or because an apparently better index was developed. While several of these indices are in use today, none have achieved a position of universal acceptability because each index appears to have shortcomings in certain environments.

In view of the absence of a universally applicable index, the particular index applied in a given study must reflect a balance between the desire for a high

level of index validity on the one hand, and the practical requirements of simplicity for application to a given study environment on the other.

The heat stress index selected for the present study was the Wet Bulb-Globe Temperature (WBGT). It has the desired simplicity, practical usefulness and is widely recommended for industrial purpose.

The WBGT index developed by Yaglou and Minard in 1957 (119) includes no parameter of air velocity and gives consideration to air velocity only through the influence of air movement on the globe temperature. From the practical point of measuring, this is an advantage since air velocity is difficult to assess in industrial situations (32). Subsequent studies (58, 66) resulted in a current American recommendation (26) of a formula for outdoor work with solar radiation, and another for indoor or outdoor work without solar radiation, using this index.

The WBGT index is the most widely used in the United States in defining occupational exposures to high temperature conditions. The National Institute for Occupational Safety and Health (NIOSH) defines a hot environmental conditions under light to moderate work as being in excess of a WBGT of 26.2^{o}C (26). Furthermore, the WBGT has been adopted as the principle index for a tentative threshold limit value (TLV) for heat stress by the American Conference of Governmental Industrial Hygienists (76). They have adapted a WBGT of 30^{o}C as the upper limit for continuous moderate work (approximately 200 Kcal/hr) for acclimatized men. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), on the other hand recommended that the WBGT not be allowed to exceed 31.3^{o}C for a 50% work 50% rest schedule (2).

B. Heat strain evaluation:

Having identified a suitable heat stress index (i.e., WBGT), the following question arises: How can the strain experienced by the worker during his normal work shift in a hot environment be evaluated with minimal interference in his freedom of motion and performance ability?

One approach which could be applied would be an attempt to evaluate his work load. Work intensities can be classified according to oxygen consumption, energy expenditure and heart rate (19). Evaluating the work load by measuring oxygen consumption is reasonably accurate. Nevertheless, the method has several drawbacks in practical industrial applications. The equipment for collecting the expired air needed for oxygen consumption measurements is rather clumsy and uncomfortable. It may impair the worker's freedom of motion and cause him to work in an unnatural way. The number of workers who can be studied simultaneously is limited because the procedure is time consuming. Finally, some additional factors of physiological stress such as heat and clothing, cannot be evaluated by changes in oxygen consumption. The result is, that in many industrial operations, measuring oxygen consumption alone gives only a partial picture of the total physiological strain. On occasion, it may even lead to an erroneous estimate of the strain involved.

An experiment, utilizing intermittent work under comfortable and warm conditions - a simulation of what might occur while a worker works his normal shift - performed by Brouha (19), serves well to demonstrate this point.

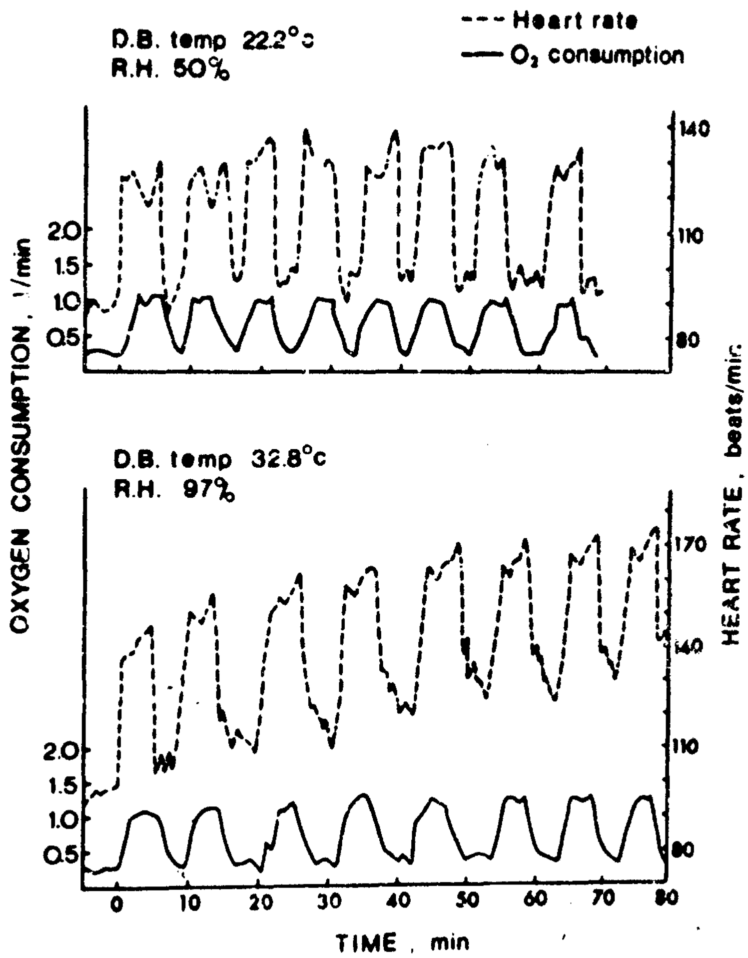
Brouha observed that the oxygen consumption behaved in a similar way in the two environments. On the other hand, the heart rate showed striking differences according to the environment (Fig. 6). The increase of circulatory strain became

rapidly more evident as the experiment in the warm environment was prolonged, but was not revealed by the concomitant change in oxygen consumption. Further, he also observed that the increases in body temperature and sweat rate was much higher in the warm environment. Thus, he concluded that the physiological strain was considerably greater in the warm environment, a fact which was not revealed by the oxygen consumption.

Brouha therefore concludes that when the environmental temperature requires an additional physiological effort to perform a given task, the oxygen consumption may not show this additional effort. The effort will, however, clearly be revealed by the heart rate changes. Consequently, under stressing conditions it is indispensible to study the cardiovascular reactions in order to evaluate the strain during work. Further, he also states that "for plant surveys, study of the heart rate reactions seems to be the most direct, simple and often the only method available for evaluating strain 'on the job'... with minimal interference in the subject's freedom of motion and performance" (19). For these reasons the heart rate was continuously recorded during the work shifts in the present study and was used to evaluate the strain.

In addition to heart rate, there are a number of other physiological dimensions which can also be used as indices of heat strain. They include: body temperatures; sweat rate; blood pressure; blood volume; kidney functions; electrolyte concentrations in the body fluids; and hormone levels (51). All of these variables were measured in the present study.

Fig. 8. Oxygen consumption and heart rate during repeated work cycles.*



Work 5 min on bicycle ergometer; the duration of the rest periods is determined by the return of oxygen consumption to the resting level.

*From L. Brouha (19).

C. General considerations:

Having noted the appropriate techniques of assessing the heat stress and strain, a general description of the workers studied during their work shifts as well as their environments must be mentioned.

The present study was conducted on the metal work shop workers of two plants in summer and winter. One plant is situated near the Dead Sea "Sdom", the lowest place on earth (mean barometeric pressure 1050 mmHG), with one of the warmest climates in the world. The other plant is in the Beer Sheva area "Beer Sheva" (mean barometeric pressure 740 mmHg) which has a semi-desert climate.

The metal work shop of Sdom is part of a large chemical plant whereas the one in Beer Sheva is a part of a large building company. Maintenance work as well as metal work projects are performed in both of these metal work shops.

The length of the work shifts of the workers of the two plants was the same (0700-1500). In both plants the workers were provided with breakfast and lunch by the plant at approximately the same times (0830 and 1230). The breakfast and lunch breaks were of equal durations in both plants. It must be pointed out, that in the opinion of this investigator the breakfast was superior in Beer Sheva while the opposite was true of the lunch. Several times during the work shifts the workers took coffee or tea breaks at the work area.

The mean age, seniority, weight, height and body surface area were similar for the two groups of workers studied (Tables 1A, B).

The workers of both metal work shops worked in a type of building which could best be described as "hangers" providing basically only a roof and having

numerous openings of various sizes on almost all directions. No heating in winter nor artificial ventilation in summer were present in the work area at either of the metal work shops.

The workers of the two plants, by the nature of their vocation, performed basically the same or similar tasks during their work shifts regardless of the season (Table 5). As a consequence of the same vocation, the workers of both plants wore similar if not the same type of clothing during their work shifts.

The workers of Sdom travelled to and from the plant by bus transportation provided by the plant, which lasted about 45-75 min depending on location of residency (Beer Sheva, Dimona or Arad). The workers of Beer Sheva arrived to the plant by their own transportation, which took them about 10-15 min.

The workers of Sdom were exposed to a higher environmental temperature and a lower relative humidity throughout the year than their counterparts in Beer Sheva (Tables 2, 3). This being particularly amplified during the summer months.

The WBGT at the work area was slightly higher in Sdom in winter while in summer the difference was greater (Table 4). In fact the WBGT in summer in Sdom was in accordance with the defination of NIOSH (26) for a hot environment and approached the recommended upper limit for light to moderate work set by the American Conference of Governmental Industrial Hygienist (76). A profile of the WBGT during a work shift (Fig. 1) shows that a major part of the work shift in Sdom in summer was above the definition of a hot environment set by NIOSH. The relative humidity was lower in Sdom than in Beer Sheva at the work area (Table 4).

Finally, it must be pointed out that the motivation for work was different in the two plants. In Sdom, the workers received a bonus if they appeared for work a certain number of days each month. On the other hand, in Beer Sheva, the workers received a bonus for completing a project or certain work on schedule and was increased if it was completed sooner. Because the salary of the workers in Beer Sheva was low it was in their interest to augment their salary by working harder and receiving the bonus. Indeed, it was observed that the workers in Beer Sheva worked harder than their counterparts in Sdom.

This observation could not be empirically documented for the following reasons: The workers as well as their union representatives strongly objected that a detailed account of the worker's activities during his work shift be documented. The fear was that the documentation might be presented or somehow be brought to the attention of the management. In effect such documentation required that the investigator dedicate his every minute of the work shift to this task. Since the study was conducted by only one investigator and in view of the strong objections raised by the workers concerned as well as the difficulty and time consuming of such a task, it was decided that only a gross evaluation be made.

D. Physiological reactions during the work shifts:

1. Heart rate:

The continuous heart rate recording was divided into seven groups of heart rates, expressed as the per cent of the work shift and presented as a profile (Fig. 2). It was observed that in Sdom there were no significant differences between the heart rate profiles between the seasons (Fig. 2). In Beer Sheva,

on the other hand, there were significant differences, especially when comparing the values of 100 beats/min and higher. It was higher in winter (Fig. 2). Further, there were almost no differences between the heart rate profiles between the two plants in summer, while in winter they were slightly higher in Beer Sheva (Fig. 3). This seemed a most peculiar situation. Given the fact that the workers of both plants were exposed to a warm environment in summer, it was assumed that their heart rates would be higher than in winter. Further, since the workers of Sdom were exposed to a warm environment in summer than their counterparts in Beer Sheva, it was also assumed that their heart rates would be still higher.

To clarify this peculiarity, it was decided to divide the work shift into two parts, the lunch break being the dividing point. By doing this, it was thought that the events possibly obscured by looking at the work shift as a whole, would be brought to light. As a result, it became apparent that there were differences in the heart rate responses between the two seasons in the two plants. This was especially true of the first part of the work shifts. The heart rate was higher in winter (Fig. 4). During the second parts of the work shifts, no differences were observed between the seasons in Sdom, while in Beer Sheva the heart rates were higher in winter (Fig. 4).

No differences between the heart rate profiles of the two plants were observed in the two parts of the work shifts in summer. In winter, on the other hand, the heart rates were higher in Beer Sheva in the first part of the work shift (Fig. 5).

In order to analyse these results, the thermal environmental conditions must be considered. The WBGT in winter in both plants was similar and could even

be considered comfortable. It must therefore follow that the strain experienced during the work shifts in this season was mainly the result of the work. If this is true, then the heart rate response indicates that the workers in Beer Sheva worked harder than their counterparts in Sdom. This was especially true of the first part of the work shift. An observation noted by this investigator.

In a warm environment, the cardiovascular system has a double role. First, it must supply enough blood to the skin for heat dissipation. Second, at the same time, it must also supply sufficient blood to the active muscles for their metabolic requirements. Thus, if identical work is performed, the heart rate is higher in a hot environment (83, 84, 115). The WBGT was found to be higher in Sdom in summer and in fact it approached the recommended upper limit for continuous light to moderate work. If the workers of the two plants worked equally as hard in summer, then it must follow that the heart rates in Sdom should be higher. This was not observed. Since there were no significant differences in the heart rate responses between the workers of the two plants, a logical conclusion would be that the workers of Beer Sheva worked harder than their counterparts in Sdom in summer.

It was previously mentioned that the heart rate responses were higher in winter in both plants than in summer for at least part of the work shift. Based on logical deduction, one would assume that the workers worked harder in winter than in summer. Indeed, it was observed that the workers worked less hard, rested more frequently and for longer periods in summer than in winter.

At this stage it must be pointed out, that the most striking feature in figures 2, 3, 4 and 5 is that regardless of the season or the plant, during

a greater part of the work shift, the heart rate was between 80-100 beats/min. It must therefore be concluded that these workers adapted themselves to work in such a regime as to regulate the strain of their cardiovascular system. Further, when the environmental temperature was high in summer and more strain was on the cardiovascular system, both groups preferred (presumably unconsciously) to perform less work. It would have been ideal if the productivity of these workers could have been compared between summer and winter in order to quantify the reduction in work performed. Unfortunately, such a comparison required expanded elements beyond the scope of this study. Furthermore, the plants refused to provide such information. In order to shed some light on this important aspect, however, a review of studies which addressed this question was undertaken.

In such studies, many investigators concluded that exposure to heat leads to a feeling of lassitude and the reduction of the ability to perform work. The evidence available comes from two types of investigations: one utilizes information from observations of the output of industrial workers who are exposed in the course of their daily work shift, to a variety of different environments; the other involved actual experimentation in which men were required to perform some specific task in a variety of controlled environments.

Relationships between a warm environment, industrial productivity, and industrial output have been reported in a series of investigations conducted for the Industrial Fatigue Research Board (in England) in the years following the first world war. Investigations in the tin-plate and iron and steel industries (59), and in glass-bottle factories (35) have revealed the influence of seasonal changes in temperature on output. Production was 10% lower in a group of tin-

plate factories in the hottest months than in the coldest. In the least well ventilated factory, the difference in production was in the order of 30%.

Even though warmth and high humidity are physically favorable for the weaving of certain textile fabrics, production of linen has been found to decline at wet-bulb temperatures above 22.8°C (109). In the cotton weaving industry, output declined at wet-bulb temperatures above 21.1°C (113).

An intensive experimental investigation carried out on the working capacity of men in different environments was conducted by Wyndham et al. (114). When acclimatized mining recruits were examined in various saturated environments ranging from a wet-bulb of 27.2 to 35.6°C, these investigators observed that the rate of filling mining cars with rock declined by only 4% as the wet-bulb rose from 27.2 to 28.9°C and thereafter fell more quickly to about 50% in a wet-bulb of 33.9°C.

Experiments carried out at normal levels of motivation conducted by Holmber and Wyon (49), Pepler and Warner (75), Johansson and Lofstedt (52) and Wyon (116) concluded that moderate heat stress lowers arousal and decreases the will to work. These experiments all used performance tests similar in nature to the work performed in schools and universities rather than in industry.

Wyon (117) conducted an experiment on the effects of moderate heat stress on typewriting performance, showed that his subjects worked satistically significantly less at 24°C than at 20°C all other factors being equal. He states the following: "Both temperature conditions were considered equally comfortable by the subjects, which suggests that they may have unconsciously adapted to the slightly raised temperature by relaxing and working less hard."

The conclusion in the present study, that the workers of both plants worked less hard in summer, thus seems to be supported by studies on productivity in a warm environment. It is therefore proposed that under the conditions of this study, the reduction of work in summer could be considered an adaptation. In other words, an adaptation of the work level, to the environment, whereby the strain on the physiological mechanisms is reduced.

There are of course, conditions in which workers in a warm environment are prevented from making this type of adaptation. A group of workers who faced such conditions were observed in Sdom.

When urgent outdoor maintenance work in the area of the "evaporation pans" was performed in Sdom by a few workers of a different department in summer, their heart rate profiles were different from those of the workers of the metal work shop. In urgent situations these workers were required to perform hard physical work in a warm environment. Their heart rate profiles (Fig. 6) show that in more than 40% of their work shifts the heart rate was above the recommended 120 beats/min (19), and in some instances heart rates above 150 beats/min were recorded for prolonged periods. Other workers of this department who were engaged in non-urgent work had heart rate profiles resembling those of the metal work shop workers (Fig. 6). A comparison of the heart rate profiles of these three groups in summer shows that when the workers did not have the option of reducing the strain of work (the work load), the heart rate was high as would have been expected.

Unfortunately, the outdoor maintenance workers in the evaporation pans were only observed during the preliminary summer studies which concentrated only on the heart rate. Because of numerous reasons, they were not studied further.

Using the heart rate response alone as an indicator of strain, the following could be concluded: In both plants the strain experienced during the work shift was greater in winter. Further, the strain was greater in winter in Beer Sheva than in Sdom and especially so in the first part of the work shift. It must also be concluded that the strain experienced during the work shifts in summer was similar for the workers of the two plants.

It was previously concluded that the work performed by the workers of the two plants was lighter in summer. Further, in both seasons it was lighter in Sdom than in Beer Sheva. Since the work heaviness varied, the heart rate response as the sole indicator of strain may not tell the whole story. The situation was further clarified, however, by analyzing the body temperatures as an additional indicator of strain.

2. Body temperatures and thermal evaluations:

Oral and skin temperatures were measured three times each work shift. These measurements were used to calculate the mean body temperatures as well as the body heat storages.

The core or internal temperature was determined by the oral temperature measurement. It was the only practical method available to which the workers did not object. It has been reported that oral temperature measurements are somewhat lower than rectal temperatures. In this regard, it should be noted that based on hundreds of measurements, Strydom et al. (98) concluded that the oral temperature is about 0.7^{o}C lower than the rectal temperature. They observed that the environmental conditions and work rate had no significant influence on the difference between oral and rectal temperatures. Further, they also observed that the mean difference remained constant over the wide range of body temperatures

investigated and did not alter at the upper limit as might have been expected.

Comparing the thermal responses between summer and winter, it was observed that the body heat storage was significantly higher in summer than in winter in Sdom. This was especially true of the first part of the work shifts (Table 6A). The higher body heat storage resulted from the higher skin temperatures during the work shifts in summer, since no differences were observed in oral temperatures. In Beer Sheva, on the other hand, the body heat storage was significantly higher in winter and especially so in the first part of the work shifts (Table 6A). It seems that the difference in body heat storage resulted from the higher increase in skin, oral and mean body temperatures in winter (Table 6A).

If the body heat storage, which embodyes the thermal responses, is considered as an indicator of strain, then the following could be concluded: In Sdom, the strain was higher in summer. Since the increase in skin temperature is mainly the result of the environment (68), it is concluded that the greater strain in summer resulted from the exposure to the warmer environment. In fact, the skin temperatures approached 36^{0}C during the work shifts in summer in Sdom, which is indeed an uncomfortable feeling.

The situation in Beer Sheva was different. The body heat storage was higher in winter. This would lead to the conclusion the strain was greater in winter. The increase in core temperature is directly related to the work load (68). Therefore the higher increase in oral temperature in winter could be interpreted as having resulted from harder work. It may therefore be concluded that the higher strain resulted from harder work in winter.

Prior to the comparison of the thermal responses between the workers of Sdom and Beer Sheva the following must be pointed out. The weighted mean skin temperatures

were observed to be lower in summer in Sdom before the work shifts than in winter (Table 6A). In Beer Sheva, the opposite was observed. The weighted mean skin temperatures, oral and mean body temperatures were higher in summer before the work shifts than in winter (Table 6A). Further, it was observed that there were differences in the body temperatures between the workers of the two plants before the work shifts in the two seasons (Table 6B). The nature of these differences are not understood.

Comparing the thermal responses between the workers of Sdom and Beer Sheva, it was observed that the body heat storages were much higher in Sdom in summer than in Beer Sheva. This resulted from the higher skin temperatures in Sdom (Table 6B). In winter the body heat storage was higher in Beer Sheva than in Sdom. This resulted from the higher increase in skin, oral and mean body temperatures during the work shifts in Beer Sheva than in Sdom in winter (Table 6B).

Based on the previous observations, it could be concluded that in summer the strain was greater in Sdom than in Beer Sheva. This seems to have resulted from the exposure to the warmer environment as could be seen by the higher skin temperatures recorded in Sdom. On the other hand, in winter the strain was greater in Beer Sheva than in Sdom. The higher increase in oral temperatures during the work shifts in winter in Beer Sheva than in Sdom indicates that the greater strain resulted from harder work in Beer Sheva.

Based on the information derived from the heart rate and the thermal responses, a better conclusion could be drawn concerning strain. In Sdom when the work shift is taken as a whole, there were no differences in the heart rate profiles while the body heat storage was much higher in summer than in winter. Therefore, it could be concluded that the strain was greater in summer, while the

work performed was lighter. In Beer Sheva, on the other hand, both the heart rate profiles and the thermal responses indicate that the strain was greater in winter. In summer, there were no differences in the heart rate profiles, while the body heat storage was much higher in the workers of Sdom than of Beer Sheva. Based on this information, it can be concluded that the strain was greater in Sdom during the work shifts in summer, while the work performed was lighter than in Beer Sheva. In winter, both the heart rate profiles as well as the body heat storage indicate that the strain was greater in Beer Sheva than in Sdom. This is in agreement with the previous conclusion that the work performed was harder in Beer Sheva than in Sdom in winter. Keeping this in mind the blood pressure reactions during the work shifts will be discussed.

3. Blood pressure evaluations:

Blood pressure was measured in the following conditions: a) after at least 15 min rest in the air-conditioned plant clinic; b) after at least 5 min rest following a bout of work, during the work shift at the work area; and c) immediately after at least 5 min of a work bout. Blood pressure in each instance was measured in the sitting position at least twice. The heart rate, at the time of the blood pressure measurement was obtained from the continuous E.C.G. recording.

It was observed that in both plants that the blood pressures measured at rest in the work area during the work shifts, were lower in summer than in winter (Tables 7A, 8A). Since the workers were exposed to a warm environment, and the skin temperatures were higher during the work shifts in summer, cutaneous vasodilation for heat dissipation undoubtly occured. Rowell (84) points out that under such conditions, there is an increase in the skin blood flow,

supplemented by the reduction in splanchnic, renal and sometimes muscle blood flows. Thus, in such a situation, the total peripheral resistance is lowered and the blood pressure decreases (84). It is therefore logical to assume that the decrease observed in the systolic and diastolic pressures in summer, resulted from cutaneous vasodilation via the decrease in total peripheral resistance.

Prior to the analysis of the blood pressure measured immediately after a work bout, some comment on the level of strenuousness of the work is in order. The heart rates at the times the blood pressures were measured, averaged about 100 beats/min in both seasons in both plants (Tables 7A, 8A). These rates indicate that the work performed when the blood pressures were measured was light (5,19).

The blood pressures measured directly after the work bouts were lower in summer than in winter only in Beer Sheva. In Sdom no differences were observed (Tables 7A, 8A). When work is performed in a warm environment there are concurrent vasodilation in the active muscles and the skin. These concurrent events cause a reduction in the total peripheral resistance, and if compensatory measures (vasoconstriction in other regions and or increased cardiac output) are inadequate, the blood pressure decreases (84). Thus, the decreased systolic, diastolic and pulse pressures observed in summer in Beer Sheva, imply a decrease in the total peripheral resistance and inadequate compensation.

The concurrent cutaneous and active muscle vasodilation, undoubtly occured during the summer work shifts in Sdom as well. Since no decrease in blood pressure was observed, the logical conclusion would be that adequate compensation occured. The only avenue of increasing the total peripheral resistance under these conditions would be vasoconstriction of visceral, renal and hepatic vascular beds (79, 81, 84). It is therefore assumed that these events occured. An increase

in cardiac output via the stroke volume is also a possibility.

During a normal work shift, the workers engaged in work and rest periods at the work area. Therefore, in order to get an overall picture of the blood pressure responses during the work shifts and especially in the warm environments, the blood pressures taken while working and those taken while resting were compared. It was observed that in both plants and in both seasons the blood pressures and heart rates were significantly higher during work than rest (Tables 9A, 10). In Beer Sheva in both seasons, and in Sdom only in winter, there was an increase in systolic and pulse pressures. This could have resulted from an increase in the cardiac output, as would be expected to occur during increased metabolic demands of work (5), and as the increase in heart rate indicates.

The situation in Sdom during the summer was somewhat different. There was an increase in the diastolic pressure as well (Tables 9A, 10). This would indicate that in addition to an increase in the cardiac output, there was an increase in the total peripheral resistance (87). The increase in total peripheral resistance was probably due to visceral, hepatic and renal vasoconstriction (79, 81).

Before drawing a conclusion on the blood pressure responses in summer, a comparison of the work heaviness at the times of the blood pressure measurements must be made. In both plants, both in summer and winter, it was observed that the heart rates recorded at the times of the blood pressure measurements were about 100 beats/min. If the same work were performed in a warm and comfortable environment, then presumably in the former, the heart rate would be higher. Since this was not observed, it is logical to assume that at the times the blood pressures were measured, the work performed in summer was lighter in both plants than it was in winter. Further, if the same work is performed in two

warm environments, one being warmer than the other, it would be expected that in the warmer of the two environments, the heart rate would be higher. Since no differences were observed in the heart rates recorded at the times the blood pressure was measured in summer, and since the environment was warmer in Sdom, then it was therefore concluded that the work performed was lighter in Sdom than in Beer Sheva.

With the above in mind, it appears that the differences in blood pressures between periods of rest and work during the work shifts in Sdom, were greater in summer than in winter, although the work performed was lighter. This could be seen by the higher increase in systolic and diastolic pressures (Tables 9A, 10). In Beer Sheva the differences were greater in winter (Tables 9A, 10). Thus the conclusion that the work performed in Beer Sheva was harder in winter, is further substantiated.

It was also observed that the blood pressures taken during work and rest at the work site were higher in Sdom than in Beer Sheva only in summer (Tables 7B, 8B). This is rather surprising, since the workers of Sdom were exposed to a warmer environment than their counterparts in Beer Sheva, and since they performed lighter work. It would have been expected that the degree of cutaneous vaso-dilation in Sdom would be greater, thereby resulting in a lower total peripheral resistance and lower blood pressures than in Beer Sheva. Since this was not the case, it may therefore be concluded that during the summer work shifts in Sdom, there was greater renal, hepatic, and splanchnic vasoconstriction, and possibly greater stroke volume, than in Beer Sheva. Presumably this was the case in winter as well.

In both plants and in both seasons, the blood pressure measurements taken at rest in the clinic before and after the work shifts were observed to be similar (Table 9B). It was therefore concluded that the effects on the blood pressure during the work shifts, did not persist while the workers rested in the air-conditioned clinic at the end of the work shifts.

It should be noted that the blood pressures measured during rest in the clinic, before and after the work shifts, were lower in summer than in winter only in Beer Sheva (Table 7A). Further only in summer there were differences in these conditions between Sdom and Beer Sheva. The blood pressures were higher in Sdom (Table 7B). These differences seem a bit odd. They could suggest a seasonal variation in the blood pressures of the workers of Beer Sheva.

A similar situation was observed by Macgregor and Loh (63). They studied British civilians and soldiers residing for varying periods in the warm environment of Singapore. Under controlled laboratory conditions, they observed that the systolic, diastolic and pulse pressures were lower after some months of residency in Singapore. Since the environment was warmer in Singapore than in England, and all other conditions being equal, they concluded that: "climatic rather than dietetic or occupational influences are primarily responsible for the variations..." Making a comparison of the cooler environment in England and the warmer environment in Singapore to the winter and summer in Beer Sheva respectively, there is some support for the seasonal variation argument.

If indeed, the observed differences in Beer Sheva were due to seasonal variations, then the question arises as to why it was not observed in the workers of Sdom as well? Without additional investigation, the scope of which would have gone beyond the parameters of the present study, there was not adequate basis on which to draw

any conclusion on this point. Thus the question can only be noted at this stage.

At this stage it could be concluded that in both plants the work performed in summer was lighter than in winter. Based on the heart rate reactions and body temperatures, it appeared that the workers in Sdom experienced greater strain in summer than in winter while the opposite could be said of their counterparts in Beer Sheva. In summer the workers of Sdom were exposed to a hotter environment, performed lighter work and showed signs of greater strain than their counterparts in Beer Sheva. It was only in this season that the blood pressures were higher in Sdom than in Beer Sheva. Analysis of the latter suggests that during the summer work shifts in Sdom there was greater renal, hepatic and splanchnic vasoconstriction and possibly greater stroke volume than in Beer Sheva. With this in mind, a discussion of the "internal environment" reactions is now in order.

E. Internal environment reactions:

In the attempt to study the internal environment reactions during the work shifts many obstacles were encountered. Many of the workers refused to have blood drawn from them. Those who finally agreed, after much persuasion, only agreed to have blood drawn before and after the work shifts. All of the workers refused to collect the urine excreted during the work shifts. They only agreed to give a urine sample before and after the work shifts. Because of practical reasons the workers could only be weighted before and after the work shifts. The nature and quantity of the food and fluid intake in the interums, could not be determined. Therefore, the data could only shed light on those changes in the internal environment, which were not fully compensated for by the end of the work shift.

Despite the above mentioned limitations, much knowledge was still derived from the analysis of the many variables in the blood and urine.

1. <u>Fluid and electrolyte reactions</u>:

Any discussion of the electrolyte and fluid reactions must take into consideration the kidney functions. Therefore, the kidney functions and responses will first be discussed.

To begin with, most of the variables of the sera which were determined (Tables 11A, B) were within the accepted normal range of the Soroka Medical Center (the central medical center of the Negev). Further, qualitative tests for glucose, protein and blood in the urine samples that were performed (with reagent strips for urinanalysis), were also found to be within the normal range. This indicated that the nephron functions were normal. Based on these determinations, it could be concluded that the kidney functions before and after the work shifts were normal. It would therefore be logical to assume that during the work shifts, the kidney functions were also normal. The question then at this point was, what further information regarding the kidney reactions during the work shifts could be derived?

The urine samples before and after the work shifts were concentrated. No significant differences were found either between the seasons or between the plants (Tables 12A, B). One explanation for the concentrated urine samples before the work shifts, is that they were either the first or second urines of the day. Since there was no fluid intake for several hours during the night, it therefore stands to reason that such concentrated urines were observed (78). In fact, when testing the maximal urinary concentrating ability, the accepted method calls for osmolality determinations of the urine, formed after all

fluids have been withheld for 10-24 hours (34, 97).

No significant differences were found between the urine osmolality before and after the work shifts (Table 12A). In order to determine the nature of the concentrated urines at the end of the work shifts, it was decided to evaluate the water handling by the kidney. The value of the urine to serum ratio (U/S) for a substance that is not reabsorbed, and which has not yet entered the filtrate directly from the blood, obviously is a measure of the degree of concentration or dilution of the filtrate due to the removal or addition of "solute-free water" (27). Creatinine, which is the end product of creatine metabolism in muscle (12, 13) and in most conditions it is excreted from the plasma via the kidney (30), i.e., the production rate equals the urinary excretion rate (18), in such a substance. Thus it was decided to use it to evaluate the renal water handling.

If the U/S creatinine ratio is 1, then the urine and the serum creatinine concentrations are equal. Therefore there is no water reabsorption from the primary filtrate by the kidney. The higher the U/S creatinine ratio the greater the water reabsorption. If the reciprocal of the U/S creatinine ratio is substracted from 1, and the difference is multiplied by 100, then the per cent water reabsorption from the primary filtrate by the kidney is determined.

It was calculated that in both seasons, and at both plants, before and after the work shifts, the per cent renal water reabsorption was higher than 99% (Table 26A). The calculated values before and after the work shifts were similar. It could therefore be concluded that the concentrated urines observed were a result of high renal water conservation.

TABLE 26A. Urine to serum creatinine ratios and renal water conservation before and after the work shifts: Sdom and Beer Sheva.

Season	Summer				Winter			
Plant	Sdom		Beer Sheva		Sdom		Beer Sheva	
Time	Before	After	Before	After	Before	After	Before	After
n	32	32	12	13	27	28	17	17
Variable								
Creatinine	*[b]239.6	[b]209.2	[b]147.9	[b]147.4	192.1	168.5	210.7	168.1
	**(99.3)	(69.4)	(53.7)	(55.5)	(86.6)	(81.8)	(127.5)	(70.9)
Per cent renal water conservation	99.6	99.5	99.3	99.3	99.5	99.4	99.5	99.4
	(0.2)	(0.2)	(0.5)	(0.3)	(0.5)	(0.6)	(0.4)	(0.3)

* Mean

** Standard deviation

a Statistically significant ($P \leq 0.05$) differences between before and after work shifts.

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva.

The concentrated urines, as well as the high renal water reabsorption, indicate that the levels of the antidiuretic hormone (ADH) were higher throughout the year. This is supported by the observations that administration of ADH to students in Beer Sheva (10), and to permanent inhabitants of hot areas (54), did not increase the urine osmolality.

The per cent renal water reabsorption was slightly higher before and after the work shifts, in summer, than it was in winter, only in Sdom (Table 25B). Further, the per cent renal water reabsorption was slightly higher in Sdom (before and after the work shifts) than in Beer Sheva, but only in summer (Table 26A). To determine what these small differences meant in absolute terms, the most direct approach would have been to compare the urine volumes. Due to the objections of the workers, the excreted urine volumes during the work shifts could not be measured and therefore had to be estimated.

The kidney functions during the work shifts were previously concluded to be normal. It was therefore assumed that the glomerular filtration rates (GFR) were normal as well. Assigning a normal GFR of 125 ml/min, as determined by creatinine clearance techniques (9) the volumes of the urine excreted during the work shifts were estimated (Table 27A).

The calculated urine volumes were about 170 ml less in summer than in winter in Sdom (Table 27B). This implies that an additional 170 ml of water were conserved in summer than in winter in Sdom. The urine volumes were also about 170 ml less in Sdom than in Beer Sheva in summer (Table 27A). This implies that an additional 170 ml of water were conserved in Sdom in summer, that were not conserved in Beer Sheva.

TABLE 26B. Urine to serum creatinine ratios and renal water conservation before and after the work shifts: Summer and Winter.

Plant	Sdom				Beer Sheva			
Season	Summer		Winter		Summer		Winter	
Time	Before	After	Before	After	Before	After	Before	After
n	18	20	18	20	8	9	8	9
Variables								
Creatinine	*220.8	[c]212.5	184.7	[c]161.3	164.5	151.9	217.4	181.8
	**(79.4)	(72.4)	(102.5)	(85.3)	(54.0)	(59.8)	(147.4)	(92.0)
Per cent renal water conservation	99.5	[c]99.5	99.2	[c]99.2	99.3	99.2	99.3	99.3
	(0.2)	(0.2)	(0.6)	(0.6)	(0.5)	(0.3)	(0.4)	(0.3)

* Mean

** Standard deviation

c Statistically significant ($P \leq 0.05$) differences between summer and winter.

TABLE 27A. Estimated urine volumes during the work shifts: Sdom and Beer Sheva.

Season	Summer		Winter	
Plant	Sdom	Beer Sheva	Sdom	Beer Sheva
Estimated urine	b*291	b460	419	418
Volume	**(80.9)	(170.1)	(318.2)	(274.2)
(ml/8 hr.)	***(29)	(12)	(26)	(17)

* Mean

** Standard deviation

*** n

b Statistically significant ($P \leq 0.05$) differences between Sdom and Beer Sheva.

TABLE 27B. Estimated urine volumes during the work shifts: Summer and Winter.

Plant	Sdom		Beer Sheva	
Season	Summer	Winter	Summer	Winter
Estimated				
Urine	c*296	c463	446	406
Volume	**(72.3)	(373.7)	(204.5)	(197.8)
(ml/8 hr.)	***(18)	(18)	(8)	(8)

* Mean

** Standard deviation

*** n

c Statistically significant ($P \leq 0.05$) differences between summer and winter.

The additional 170 ml of water conserved during the work shifts in summer could not possibly have affected the water balance of these workers. In the present study it was not possible to measure the sweat rate, but studies conducted by Toor et al. (100) in Sdom during the summer, found that the sweat rate was several liters (6-10 liters) during each work shift. Therefore, in light of Toor's studies 170 ml probably made very little difference in the maintenance of water balance. The same argument holds true for the differences in summer between Sdom and Beer Sheva.

It is therefore suggested that the water conservation mechanisms were already near maximum in winter. This being the case, they could not in any practical way meet the increased demands of water conservation in summer. Since it became clear that the small differences in reabsorption had little impact, a question as to whether fluid balance was in fact maintained, and if so how, therefore was posed.

One indication of whether, fluid intake and losses were similar, could be approximated from the recorded weight differences. In summer there was no weight loss (rather a gain) in the workers of Sdom, while in Beer Sheva an average weight loss of 0.4 Kg was observed (Tables 6A, B). It could be concluded, that in summer the fluid intake was somewhat less than the loss of fluid in the workers of Beer Sheva. In Sdom, in both seasons, and in Beer Sheva in winter there were no weight losses, probably because the fluid intake and losses were similar. In fact, it is likely that fluid balance was maintained during the work shifts. Since the water conserving mechanisms were working near maximum even before work began, they could not have played a practical role in maintaining fluid balance. Thus the fluid losses were replaced by proper fluid intake, thirst being the mechanism responsible for

maintaining proper fluid balance during the work shifts. With this in mind, the changes in the volumes of the blood, plasma and red blood cells during the work shifts were evaluated.

The percentage changes in blood, plasma and red blood cell volumes during the work shifts, were calculated from the changes in hemoglobin and hematocrite (29). Several investigators have considered this method of determining these changes to be the best indirect method available (45, 50, 92). One condition had to be met before this method could have been employed. That condition was, that the circulating red blood cell mass had to be stable during the investigated period. This condition was assumed to have been met in the present study, since reported measurements before, during and after exercise at a variety of stress levels, have not detected any meaningful changes in circulating red blood cell mass (4, 33, 70, 101).

It was calculated that in both plants, in both seasons, there was a volume expansion during the work shifts. There were increases in blood and especially plasma volumes with a slight reduction in the red cell volume (Table 28A). A volume expansion has been observed in controlled laboratory experiments while mild work was performed in cool and comfortable environments (21, 56, 90, 110). This has also been observed in heat acclimatized subjects at rest (1, 6, 37, 57, 88, 89) and in those performing mild work (41, 90) in a warm environment. These studies explain the volume expansion, as resulting from protein movement accompanied by water and ions from the interstitial spaces to the vascular volume. In the present study, the concentrations of the proteins and ions moved into the vascular volume seem to have been similar to those of the original plasma. The lack of changes in serum osmolality (and protein) would further support this observation.

TABLE 28A. Changes in blood, red cell and plasma volumes during the work shifts: Sdom and Beer Sheva.

Season	Summer		Winter	
Plant	Sdom	Beer Sheva	Sdom	Beer Sheva
n	32	13	28	17
Variable				
+ΔBV (%)	*4.9	2.4	2.9	4.7
	**(5.5)	(4.5)	(9.4)	(6.8)
++ΔCV(%)	-0.4	-2.1	-2.1	-2.9
	(3.4)	(4.3)	(8.5)	(9.1)
+++ΔPV(%)	9.6	5.5	7.7	12.5
	(8.9)	(6.5)	(12.6)	(7.3)

+ ΔBV(%) per cent change in blood volume.

++ ΔCV(%) per cent change in red cell volume (RBC).

+++ ΔPV(%) per cent change in plasma volume.

* Mean

** Standard deviation.

TABLE 28B. Changes in blood, red cell and plasma volumes during the work shifts: Summer and Winter.

Plant	Sdom		Beer Sheva	
Season	Summer	Winter	Summer	Winter
n	20	20	9	9
Variable				
+ΔBV(%)	4.6	1.7	3.4	6.0
	(5.6)	(9.7)	(5.0)	(7.2)
++ΔCV(%)	-0.5	-3.4	-1.4	-2.8
	(3.5)	(6.8)	(4.4)	(10.2)
+++ΔPV(%)	9.2	6.6	[c]7.5	[c]14.3
	(8.6)	(14.1)	(6.8)	(5.9)

\+ ΔBV(%) per cent change in blood volume.

++ ΔCV(%) per cent change in red cell volume (RBC).

+++ ΔPV(%) per cent change in plasma volume.

* Mean

** Standard deviation.

c Statistically significant ($P \leq 0.05$) differences between summer and winter.

In both plants the total protein serum concentrations were significantly higher in summer than in winter (Table 11B). This has been reported previously (91) and seems to be a fundamental factor in the process of heat acclimatization. In fact, the intravascular protein mass has great physiological importance because it determines the intravascular water-binding capacity (80).

Having discussed the kidney and body fluids reactions, sodium and potassium balance will now be discussed. In both seasons, in both plants, the serum sodium concentrations (Table 11A) were within the accepted normal range of the Soroka Medical Center. It was observed that the differences of sodium concentrations during the work shifts in both plants were slight if at all. These differences were also slight between both seasons as between the two plants (Tables 11A, B). Thus, it was concluded that the workers in both plants maintained sodium balance during the work shifts both in summer and winter.

In summer, the sweat rate was undoubtly higher than in winter. The sodium loss in the sweat would therefore have been higher. Since it was observed that in summer, the sodium concentrations were even slightly higher at the end of the work shifts than in the beginning of the work shifts, it seems that sodium intake during the work shifts was adequate. Increased renal reabsorption or conservation was a possibility as well.

In Sdom in both seasons (and especially in summer) the serum potassium concentrations were high (Table 11A). In both seasons there was a decrease in the serum potassium concentrations at the end of the work shifts (Table 11A). This decrease was greater in summer than in winter. Possible explanations to these observations could be losses in sweat and or renal secretion.

In Beer Sheva, the serum potassium concentrations were slightly lower than in Sdom (Table 11A). The nature of these observations are not understood. Further, no significant changes occured during the work shifts in Beer Sheva (Table 11A).

In Sdom the potassium serum concentrations before the work shifts in summer were significantly higher than in winter, while the opposite was observed in Beer Sheva (Table 11B). Henrotee et al (47, 48) have obtained evidence of a significant climatic variation associated with a lowered potassium tolerance and a higher plasma potassium level in hot environments. This seems to explain the observations in Sdom but not in Beer Sheva.

Based on the above discussion, it was concluded that fluid and sodium and potassium balances were maintained during the work shifts. Another aspect of the internal environment, the hormonal reactions will now be discussed.

2. Hormonal reactions:

a) Aldosterone: The action of aldosterone has been reported to exert a renal sodium reabsorption while secreting potassium (78, 112). Therefore, in order to better understand the serum sodium and potassium observations, the serum aldosterone was assayed.

Only the serum sodium and potassium of those workers whose aldosterone serum levels were assayed are considered (Table 29). It must be pointed out that the serum sodium and potassium of these workers were similar to the rest of the workers.

The only significant differences in the aldosterone levels before and after the work shifts were observed in Beer Sheva in winter (Tables 26, 13A). This

TABLE 29. Serum sodium, potassium and aldosterone levels determined on the same workers.

Plant		Sdom				Beer Sheva			
Season		Summer		Winter		Summer		Winter	
Time		Before	After	Before	After	Before	After	Before	After
n		11	11	11	11	6	6	6	6
Variable	Units								
Na	mEq/l	*140.3	141.3	137.9	138.5	138.5	139.8	138.3	137.5
		**(4.3)	(2.9)	(0.8)	(1.5)	(1.8)	(1.6)	(1.0)	(1.8)
K	mEq/l	c5.4	4.5	c4.7	4.2	c3.4	c3.6	c4.4	c4.1
		(0.8)	(0.4)	(0.5)	(0.3)	(0.2)	(0.3)	(0.5)	(0.2)
Aldosterone	Pg/ml	c98.8	83.1	c59.3	58.1	102.1	93.5	110.5	74.6
		(27.7)	(38.3)	(35.3)	(35.9)	(38.3)	(38.2)	(44.5)	(41.2)

* Mean

** Standard deviation.

c Statistically significant ($P \leq 0.05$) differences between summer and winter.

does not explain the observations of the serum sodium and potassium concentrations. In fact if anything at all occured during the work shifts, it was a slight decrease in the aldosterone levels (Table 13A).

The aldosterone levels in Sdom were observed to be higher in summer than in winter (Table 13B). These levels were similar to those observed in Beer Sheva. In fact it was in winter that there were differences. The levels were lower in Sdom (Table 13A). It would therefore be logical to conclude that in summer the salt retaining activity of aldosterone was similar in both plants, while in winter it was higher in Beer Sheva. The situation in winter is somewhat odd. The only thing that could really be said about the aldosterone levels is that in both seasons, in both plants they were within the normal range.

In summary it could be said that no increased salt-retaining activity of aldosterone was observed. Since salt balance was maintained during the work shifts, it would be logical to conclude that it resulted from proper salt intake.

b) Cortisol: The major glucocorticoid hormone, cortisol, was assayed in the sera. It was observed that in both seasons, in both plants, there was a significant decrease in the serum cortisol levels at the end of the work shifts (Table 13A). This is in agreement with the reported diurnal rhythm of cortisol secretion (15, 36, 72, 108). It would therefore seem that nothing unusual occured in the secretion of cortisol during the work shifts.

Only in Sdom were there significant differences between the two seasons. The cortisol levels were significantly lower in summer than in winter (Table 13B). This is in contradiction to the reported increase in cortisol secretion under

hot conditions (24).

The overall pattern of cortisol action might be viewed as promoting the conversion of protein to carbohydrate and the storage of carbohydrate in the form of glycogen (3). Its most important biological effects could be briefly summarized as: a) deposition of glycogen into the liver, b) production of glucose from amino acids and c) delay of glucose oxidation (73). Since these effects were not studied in the present investigation, it is difficult to evaluate the significance of the lower serum cortisol levels observed in Sdom in summer than winter.

c) Thyroid hormones: In the present study, the total serum concentrations of thyroxine (T-4) and triiodothyronine (T-3) were determined. T-4 and T-3 circulate both as free hormones and as bound complexes to specific serum proteins. It is generally recognized that the free fractions are the biologically active components and the bound fractions are inert (46, 53). It was therefore assumed that determinations of the free thyroid hormone concentrations in serum would comprise the best method for study of thyroid function. It has been reported that the free hormone determination is unlikely to play a major role in the study of thyroid function (120). One reason for this conclusion was the statistically significant correlation found between the free hormone levels and their respective total hormone levels, and the fact that the estimation of the free levels were more complicated than of the total levels (120).

In the present study, it was observed that in both seasons, in both plants, the serum T-3 and T-4 levels were within the normal range (Table 13A). The most obvious observation was that in both plants there was a significant increase in

the serum T-4 levels in summer as compared to winter, while the exact opposite was observed regarding the serum T-3 levels (Table 13B). The increase in serum T-4 levels was about 20% while the decrease in T-3 was about 10%. It was also observed that in both plants the T-3/T-4 ratio was significantly lower than in winter (Table 14B). It was about 25% lower in summer.

While T-4 is the main hormone secreted by the thyroid gland (99), T-3 is the biologically active hormone (11, 71, 85, 86, 99). The source of circulating T-3 in normal man is largely the extra-thyroidal monodeiodination of T-4 (16, 69, 77, 96). Therefore, the significant increase in serum T-4, decrease in T-3 and lower T-3/T-4 ratios observed in summer would suggest that the conversion rate of T-4 to T-3 was lower in both plants. In fact, previous investigators have regarded a normal serum T-4 level, and a decrease in serum T-3 concentrations, to be due to inhibition of the conversion of T-4 to T-3 (62). Thus the altered peripheral metabolism of T-4 degradation into the metabolically more active T-3, or to the metabolically inactive reverse-T-3, may be a significant regulator of body metabolism. The control mechanisms responsible for the hormonal changes are still unknown. The fact that the changes have been observed in a variety of non-thyroidal diseases involving different organ systems, may indicate that the monodeiodination can be controlled by different mechanisms, and can occur at multiple sites.

It is thus suggested that the reported decrease of thyroid function in men living in hot climates (23, 38, 43, 44, 60, 74), results from an altered peripheral metabolism of T-4 degradation into the metabolically more active T-3; rather than a decreased activity of the thyroid gland.

In summary, it may be concluded that the workers of both plants practiced economy in their energy expenditure, which reduced the heat stress in summer.

This was probably greater in Sdom than in Beer Sheva. The practical results were a decrease on the demands for evaporative cooling and heat dissipation. This was of great importance on the cardiovascular system as well as on the fluid and electrolyte balance. These findings enable a better understanding of the slight changes in the blood variables during the work shifts. In so far as the salt and fluid balances were concerned, it seems that these were maintained by proper fluid and salt intake during the work shifts. The concentrated urines, low volume, very high renal water reabsorption, and inferred high levels of ADH would suggest that the water conserving mechanisms were performing almost at maximum. Further, the high serum concentrations of protein and hemoglobin would imply that there was some degree of hemo-concentration. This was observed in both plants, and in both seasons, even before work began. Therefore the clear indication is that this condition existed throughout the year. It would appear during the work shifts, water and salt balance was maintained, but these workers seemed to be somewhat less hydrated than the level reported as normal in most medical textbooks. Further research needs to be done before a definite conclusion could be made on the state of hydration of these workers.

II. Survey of disorders of the cardiovascular and urogenitial systems:

An attempt was made to determine if the strain on the physiological systems concerned with thermoregulation imposed by work in a hot environment might lead to disorders. Many obstacles were encountered in this attempt. The number of workers who worked in the plant in Sdom was small in comparison to the accepted size for such a survey. Further, not all the workers of the plant were exposed to the hot environment during their work shifts. Upon review of the archives of the plant, they were found to be incomplete in several respects. It could

not be determined if the employees who terminated their employment prior to retirement did so because of medical reasons. It was also not possible to determine if workers who were transferred from jobs where they were exposed to heat, to jobs where they were not, was due to medical reasons. When it came time to compare the data on this subject from Sdom, with the data from Beer Sheva it became evident that such comparisons were almost impossible. The problem was that each plant had many unique factors which did not exist in the other and which could significantly affect this type of survey. The time spent on travel to and from the plants, salaries, motivation, developmental stages of the plants, hiring and firing practices of the plants, and medical follow up on the workers differ from plant to plant. It is also difficult to find two plants with approximately the same labor force and age composition. For all of the above reasons, and because it is the hotter of the two environments, it was decided to concentrate this part of the research mainly on the plant in Sdom.

The data derived from the certificates of illness, as well as the electrocardiogram and blood pressure examinations were compared between workers who were exposed to a warm environment (heat exposed) and those who were not (unexposed). It must be kept in mind that a worker whose health was adversely affected during his employment would not have been transferred to work where they would be exposed to heat. The contrary might be true however. Thus a worker suffering from a disorder of the cardiovascular system, and who was exposed to a warm environment during his work shifts, would not have gotten assigned to this type of job. Rather this condition would most likely have resulted from on the job exposure.

A. <u>Certificates of illness of the workers of Sdom:</u>

It was initially observed that approximately 70% of the employees of the plant

were exposed to heat during their work shifts, 30% were not. It was further observed that among those workers who were suffering from disorders of the cardiovascular and urogenitial systems, only about 70% were heat exposed workers, while the remaining 30% were not (Table 15). It would thus appear that the occurence of these disorders was independent of the thermal environment. In order to clarify this point, it was decided to analyze the workers suffering from cardiovascular and urogenitial system disorders, in relation to age and seniority. Due to the small number of workers, it was decided to randomly divide the groups into two age sub-groups: those younger than 46; and, those 46 and older. The same was done concerning seniority. The groups here consisted of those with less than 11 years, and those with 11 or more years.

Within the subgroup of workers who suffered from cardiovascular and urogenitial disorders and were younger than 46, there were proportionately more unexposed workers (Table 16). The same was observed concerning those who worked less than 11 years (Table 17). It seemed very odd that the workers who experienced less strain were more ill. The only way such a situation could have resulted, is that more workers who were exposed to heat, and had cardiovascular and urogenitial disorders, had left the plant without their conditions being recorded. The observations of Minard et al., (67) seems to support this conci - sion. They state the following: "The workers in hot jobs are a highly select population. Workers who feel that they cannot cope with the prevailing heat stress change their job for a less demanding one. As a result of this natural selection process, the majority of the workers in the hot jobs have high levels of physical performance and capacity and are highly adaptable to work in the heat."

The proportion of the heat exposed workers within the subgroup who suffered from cardiovascular and urogenitial disorders and were older than 46 was greater (Table 16). The same was observed concerning the seniority group greater than 11 years (Table 17). A possible explanation for this observation is that while the younger employees had the option of mobility within the plant or outside the plant, the older ones, even when their health was adversely affected were limited because of socioeconomic resaons. Thus they remained at their jobs. Again the observations of Minard et al., (67) (on steel workers) seems to support this conclusion. They state: "Because jobs in hot environments may be better paid than other jobs, it often happens that workers try to stay with the hot jobs even after their health or fitness becomes inadequate for the job. Since there is no obligatory standard for physical fitness to these jobs, and since periodic medical examinations have been haphazardly done in many industries, if at all, these workers stay on the job and run a high health risk."

At this stage the data from the certificates of illness indicate that a natural selection process may have occured in the heat exposed workers. Further, it seems that the heat exposed workers' health may have been adversely affected by work in the hot environment.

B. Electrocardiogram and blood pressure examinations in Sdom:

In order to validate some of the data derived from the certificates of illness, electrocardiogram (ECG) and blood pressure examinations were performed on a representative group of workers (about half of the plant) (Fig. 7). It was observed that within the subgroup of workers who were diagnosed as having an abnormal ECG and hypertension there were proportionately more heat exposed workers (Table 18). This was also true regarding age and seniority (Tables 19, 20).

Regarding the younger workers and those who worked less than 11 years, there seems to be a contradiction between the data derived from the certificates of illness and the examinations. This was due to the fact that not all the workers who were diagnosed as having abnormal ECG and high blood pressures were aware of their conditions. For example, the certificates of illness indicated that 33 workers from the whole plant suffered from hypertension, while 34 workers from approximately 50% of the plant who were examined, were found to have abnormally high blood pressures. Only 14 knew of their condition.

Besides the above mentioned group of workers who were consistently found to have abnormally high blood pressures (both at work and at home), there were 24 other workers, most of whom were heat exposed, whose abnormally high blood pressures were recorded only in the plant clinic in Sdom. Repetitive measurements taken in summer at their place of residence (Arad, Beer Sheva or Dimona) by their family physician showed that their blood pressures were normal. On the average the systolic pressure was about the same while the diastolic pressure was 19 mmHg higher in Sdom than at their place of residence (Table 21). In winter, two and a half years later 14 of these workers underwent additional blood pressure measurements in Sdom. The blood pressures of 10 of these workers were lower than they were in summer. On the average, the systolic pressure was similar while the diastolic pressure was about 15 mmHg lower than in summer (Table 22). Further, the blood pressure of these workers in Sdom in winter was similar to those measured at their place of residence in summer (Table 23). The blood pressure of the other 4 (all of who were heat exposed) taken in Sdom was the same in both summer and winter. In fact one of the four workers has since been diagnosed as hypertensive and is undergoing treatment.

Based on the above findings, it would seem appropriate to label this group the "transitional" group. That is, those workers who are on their way to developing hypertension. The existence of four workers whose blood pressure was high in summer and in winter, as well as the fact that one of them is already undergoing treatment for hypertension seems to support this argument. A follow up of these workers in the future should provide the answer.

It would appear that the cause of the hypertension is the work in a hot environment. The previous discussion points out that only in summer in Sdom were the blood pressures of the transitional group above normal. Further, the measurements were performed during the work shifts after the workers rested for at least 15 min. and while in the air-conditioned plant clinic. The blood pressure measurements conducted on the metal work shop workers also seems to support this conclusion. Only in summer were there differences in the blood pressures between the workers of the metal work shop in Sdom and those in Beer Sheva. They were higher in Sdom (Tables 7B, 8B). Further, the diastolic pressure measured after work bouts in summer, were about 10% higher in Sdom than they were in Beer Sheva. This lends even more support to the conclusion, since it was observed that the major difference in the transitional group was in the diastolic pressure. Further evidence comes from the blood pressure comparison of rest to work periods. Only in Sdom in summer was the diastolic blood pressure higher during work than in rest (Tables 9A, 10).

In summary, it would seem that the data from the certificates of illness and the examinations indicate greater incidences of cardiovascular and urogenitial system disorders among heat exposed workers, than among their unexposed counterparts. This is also supported by the results of other surveys (8, 17, 103) which were conducted on larger groups of workers. The data also indicates that there is a

process of natural selection whereby during the first few years, the heat exposed workers who are adversely affected either transfer to less demanding jobs or leave the plant. The older workers are unable to do this.

C. Comparison of disorders of the cardiovascular and urogenitial systems between Sdom and other work environments:

When comparing the frequencies of these illnesses in Sdom to Beer Sheva, it seems that in Beer Sheva they were higher (Tables 24, 25). As previously stated, this comparison can not be completely validated. The age and seniority of the workers in Beer Sheva were higher than in Sdom (Fig 7). From personal discussions with the workers, it became apparent that the turnover of workers was much higher in Sdom than in Beer Sheva. Further, there may have been other factors besides the heat which may have contributed to these illnesses in both plants. These factors may not have been present, or at least not present to the same degree in both plants however.

It is also difficult on the basis of the data available to come to a firm conclusion as to whether the frequencies of these illnesses are higher in the heat exposed workers in Sdom, than would be the case in the rest of the population in Israel. First, as previously stated, the medical data on those workers who left the plant prior to retirement was unavailable. Second, very few such surveys have been conducted in Israel. Those that have been done, have been limited to males aged 40 and above. Most of them consist predominately of clerks rather than industrial workers (39, 65, 94). Also, the conditions of the studies were not the same.

With the data available these type of comparisons are rather futile. Therefore the emphasis was placed on the comparisons between the heat exposed and unexposed

workers in Sdom.

III. Conclusions:

Based on the ergonomic studies, it was concluded that the heat exposed workers practiced economy in their energy expenditure and thus reduced the heat stress. The studies of the internal environment indicate that the fluid and salt balances were maintained during the work shifts probably by proper intake.

The data from the survey of cardiovascular and urogenitial disorders suggests that the process of natural selection plays a role in the younger workers. Those who were adversely affected by the heat stress probably changed their jobs. Further, it is suggested that the health of the workers who were exposed to heat during their work shifts may be more adversely affected than those who were not. It is also suggested, that this is especially true for those who could not practice economy in their energy expenditure.

SUMMARY:

The question of whether working in a hot environment may ultimately be a health hazard was the subject of this investigation. The study was conducted on the employees of two plants. One plant is situated near the Dead Sea "Sdom", the lowest place on earth (mean barometeric pressure 1050 mmHg), with one of the hottest climates in the world. The other plant is situated in the Beer Sheva area "Beer Sheva" (mean barometeric pressure 740 mmHg) which has a semi-desert climate.

During work shifts the mean range of air temperatures was from 30-36^{o}C (May-Oct.) and 14-21^{o}C (Dec.-Feb.) in Sdom and 25-32^{o}C (June-Sept.) and 10-7^{o}C (Dec.-Feb.)

in Beer Sheva.

The study was divided into two phases: 1) Ergonomic and physiological studies during the normal work shifts on healthy workers of the metal work shop in both plants in summer and winter and 2) Survey of cardiovascular and urogenitial disorders.

Before and after the work shifts, the worker was weighted and blood and urine samples were obtained in the plant clinic. The ECG was continuously recorded during the work shifts and several times the blood pressure was measured. Skin and oral temperatures were measured three times during the work shifts. At the begining and end of each work shift the wet bulb, dry bulb and globe temperatures were measured at the work area.

The Wet-Bulb-Globe Temperature index (WBGT) values in the metal work shops in summer were higher in Sdom than in Beer Sheva. In winter they were similar at both plants. The summer WBGT values in Sdom were usually in excess of the minimum (WBGT = 26.2^{o}C) for a hot environment as defined by the National Institute for Occupational Safety and Health (NIOSH) and approached the recommended upper limit for continuous light to moderate work in a hot environment.

Continuous ECG recordings showed that in both seasons in both plants the heart rates were between 80-100 beats/min for at least 50% of the work shifts. No significant differences were found between the heart rate profiles between summer and winter in Sdom while in Beer Sheva it was slightly higher in winter.

Heart rate profiles of outdoor maintenance workers performing urgent work in summer in Sdom were different than those of the workers of the metal work shop. During about 40% of the work shifts the heart rates were above 120 beats/min.

Those workers who did not engage in urgent work showed heart rate profiles similar to those of the metal work shop workers.

The serum concentrations of urea, uric acid, sodium, potassium, albumin, hematocrite and osmolality were within the values accepted as normal at the Soroka Medical Center in Beer Sheva. The serum concentrations of creatinine and hemoglobin and potassium (only in Sdom) were on the upper limit of the normal range. The serum concentrations of total protein and globulin were higher than the normal range. There were almost no changes of these variables during the work shifts nor between the seasons in both plants. Further, the differences between the plants were small if at all. The serum levels of aldosterone, cortisol, thyroxine and triiodothyronine were within the normal range. An increase in the blood and especially in the plasma volumes with a slight decrease in the red blood cell volumes were calculated in both seasons during the work shifts. The urines before and after the work shifts in both seasons in both plants were concentrated (about 900 mOsm/Kg). The calculated renal water reabsorption was higher than 99%.

Based on the heart rate recordings, it is suggested that these workers practiced economy of energy expenditure in summer and thus reduced the heat stress. This probably had great importance on the electrolyte and fluid balance as well as on the cardiovascular system. Further, the lack of weight loss, almost maximal urinary water conservation already in winter would indicate that fluid balance was maintained in the hot environment by proper fluid intake. The lack of changes in the aldosterone levels in summer would indicate that the salt balance was maintained as a result of proper salt intake.

The high serum protein and hemoglobin concentrations, concentrated urines, extremely high renal water conservation, low urine volumes and inferred high levels

of ADH in winter would indicate that the state of hydration of these workers was probably lower than the accepted "normal" levels reported in most medical textbooks.

The survey of urogenitial and cardiovascular disorders were conducted in two stages and focused primarily on the workers of the plant in Sdom. First, the certificates of illness of all the workers of the plant (769) from Jan.1, 1971 to Dec. 31, 1976 were collected. 47 employees were found to be suffering from diseases of the cardiovascular system (functional heart disease, arterioscleratic and degenerative heart diseases); 7 from coronary diseases: 33 from hypertensive diseases; and 60 from diseases of the urogenitial system. Workers who were exposed for a major part of their work shifts to the hot environment during summer were grouped together and termed "heat exposed" and the rest as "unexposed". Further, the workers were divided into two age groups - under 46 and over 46 years - and two seniority groups - less or more than 11 years of employment. The data from these certificates indicate that within the subgroups of workers who suffered from cardiovascular and urogenitial disorders and were under 46 there were proportionately more unexposed workers. The same was observed regarding the seniority group less than 11 years. On the other hand, the proportion of the heat exposed workers within the subgroup who suffered from cardiovascular and urogenitial disorders and were older than 46 was greater. The same was observed for the seniority group of 11 years and more. These data indicated that there was a selection process among the young workers. The workers who were adversely affected by the heat either transferred to other jobs or left the plant.

In the second stage, half the workers of the plant (398) underwent ECG and blood pressure examinations during summer work shifts following a period of at least

15 min rest in the air-conditioned plant clinic. The ECG of 30 workers were found to be abnormal and the blood pressure of 34 were found to be abnormally high in Sdom as well as in their place of residence. The data from these examinations indicate that within the subgroup of workers who were diagnosed as having an abnormal ECG and hypertension there were proportionately more heat exposed workers.

24 other workers, most of whom were heat exposed had abnormally high blood pressures during measurements performed on several days only in Sdom. On the other hand, measurements taken in summer at their place of residence by their family physician showed that their blood pressures were normal. The major difference was that the diastolic pressure was about 18 mmHg higher in Sdom. In winter, two and a half years later, 14 of these workers underwent additional blood pressure measurements in Sdom, (under the same conditions as in summer). The blood pressures of 10 of these workers were lower than they were in summer. Again the major difference was in the diastolic pressure. It was about 15 mmHg higher in summer. The blood pressure of these workers in Sdom in winter was similar to those measured at their place of residence in summer. The blood pressure of the other 4 (all of whom were heat exposed) in summer and winter was the same. One of the 4 workers has since been diagnosed as hypertensive and is undergoing treatment. This seems to suggest that the cause of the abnormally high blood pressure was work in the hot environment. This is further supported by the blood pressure measurements conducted on the workers of the metal work shop workers during their normal work shift. The blood pressures were higher during the work shifts in Sdom than in Beer Sheva, only in summer. The diastolic pressures measured after work bouts in summer were about 10% higher in Sdom than in Beer Sheva. Further, only in Sdom in summer were

the diastolic pressures higher during work than in rest.

Based on the data from the certificates of illness and the ECG and blood pressure examinations, it is suggested that work in a hot environment may present a health hazard. Further, it is suggested that the health of those workers who were exposed to heat and could not practice an economy in energy expenditure was most likely adversely affected.

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